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Effectiveness for Storage and Service

EQUIPMENT SHOULD BE CHOSEN FOR EFFECTIVENESS, RELIABILITY AND LOWEST TOTAL COST, CONSIDERING INVESTMENT, OPERATION AND MAINTENANCE. BY STAUNTON B. PECK*

OF ALL COMMODITIES, coal is probably subject to the most irregular or fluctuating demands; and these demands must be promptly met. Coal is a necessity, not a luxury or convenience that can be temporarily dispensed with, if not available at the moment.

Not only is the coal market subject to the ups and downs of general business conditions, but it is affected by others of much greater variability, the weather, of course, or "seasonal demand" having the greatest influence. Strikes are a disturbing factor in any field of endeavor and the coal mines have had their full share of these. Car shortages and other difficulties of transportation at times contribute to the irregularity of coal production and distribution.

Seasonal demand accounts, according to statistics of the U. S. Geological Survey, for 50 per cent variation between months of high and low production and for 100 per cent variation between high and low months over a 2-yr. period. The peak demands must be met, which means a wide fluctuation in production or a stored reserve of coal on which to draw.

IDLE MINES INCREASE COAL PRICES

Development of a productive capacity approximately equal to maximum demand has taken place during the past decade, which is obviously uneconomical and has resulted in high pay for the time worked to offset the many hours of idleness of workers. This high hourly rate enters into the high price that the consumer pays, as does the overhead on mining equipment which is idle so much of the time. The consumer is, therefore, vitally interested in development of storage methods, which will meet maximum seasonal demand from a reserve accumulated during low demand periods, thus meeting market requirements with a minimum of workers and invested capital.

Not only is the general demand for coal subject to seasonal fluctuations, but this variation in demand affects the different sizes; and, as these sizes are for the most part produced not independently but simultaneously, storage facilities will take care of a size for which no market exists at a time when some other size is in active demand. A foremost and very real argument, therefore, exists for storing the coal supply, in the recognized gains that accrue to any industry from uniformity and continuity of operation.

STORAGE INVOLVES EXPENSE

Objections to storage, particularly from the operators' standpoint, are, of course, apparent. Storage involves an investment in ground and with greater or less trackage facilities; equipment, with maintenance and depreciation costs; handling charges; some deterioration of the coal, perhaps; the risk of spontaneous combustion; and finally, inactive capital locked up in the stored product itself. To add to this burden, taxes have, at times, been imposed on the value of the stored coal by the Main Street solons of some of our state governments. Needless to say, this is a short-sighted policy tending to discourage a practice which is beneficial in its purpose and results to the whole community. It has resulted in the removal of some storage plants to other localities and the entire abandonment of others.

While all these costs are initially borne by the mine operators and the distributors, they must ultimately find their way to the consumer. Storage may, therefore, be classed as a necessary evil, hence it is a matter of concern to everyone that the utmost wisdom be exercised in determining advantageous locations, quantities to be stored and the most economical handling methods.

Storage at the mine for sizes unmarketable when

*Consulting Engineer, Link-Belt Co.

produced and to permit continuous operation in case of car shortages has been found advantageous and calls for little additional equipment. But, for seasonal storage, ground suitable for storage space and track facilities are often not available and railroad blockades due to strikes or weather conditions may render the reserve unavailable when most urgently needed.

Strategic centers of distribution nearer the consumer are usually and wisely sought. The prohibitive cost of land makes it inadvisable to locate these actually within our large cities but they can usually be placed adjacent to some outlying service yard or belt line, with the maximum availability under the most unfavorable conditions.

Storage at tidewater for export and shipment to domestic points reached by water transport are advantageous, can be located on inexpensive land and need only simple equipment for storing and reloading, such as locomotive cranes and drag scraper plants. Also Duluth and Superior are an example of utilizing cheap water transport during open summer months by ore and grain ships which otherwise would go unloaded, thus reducing the rail haul in winter when conditions are difficult. Study of conditions will probably disclose other locations where like advantages may be secured.

Public service companies have generally provided storage to care for minor contingencies but the railroads seem to prefer to take advantage of their ability to confiscate coal in transit and to keep considerable amounts in cars, a most uneconomical form of storage, which ties up expensive equipment, congests yards and sidings and obstructs traffic.

Railroads and public utility corporations of necessity must and do have such storage of coal on hand as will ensure them for a considerable period of time against interruption of their service; and their equipment should be of considerable flexibility so that with economy the amount of coal in storage may be reduced or increased as wise foresight dictates. Manufacturing companies, particularly the larger ones, all recognize the importance of storage facilities as a safeguard to interruption of their activities.

Factors Influencing Choice of Coal-Handling Equipment

Description and discussion of the detail methods employed in storing coal hardly come within the scope of this article. What determines the plan and equipment is influenced by many considerations. The size and shape of the site may have much to do with it. The rapidity with which the coal must be stocked or reclaimed is a controlling factor, as is the frequency with which it is handled.

Some bituminous coals are liable to spontaneous combustion, which makes it essential that they be piled rather low, hence relatively large areas for given quantities stored are required. Obviously any structures or trestles in the coal itself should, in this case, be avoided and the mechanical equipment should be of such a character that the burning area can be quickly reached and uncovered. Overhead cranes or bridge tramways with grab buckets, or locomotive cranes similarly equipped on tracks adjacent to the stored coal best serve this purpose. Locomotive or crawler cranes indeed are particularly useful for storage and reclaiming, as when not engaged in this service they may be of utility for various other purposes about a plant.

The drag scraper method is well suited for emergency or reserve storage infrequently handled, as it is adapted to storing considerable quantity of coal at a minimum initial outlay for equipment and the maintenance cost is small.

Storage of anthracite presents quite a different problem from that of bituminous coal. The latter is usually stored as mine-run but, even when sized coal is stored, breakage is of relatively little importance. With the former there are wide differentials between the prices of the carefully prepared sizes and the small sizes, or degradation, so-called, that result from breakage; it is, therefore, a matter of supreme importance to reduce this breakage in the handling, to a minimum.

All anthracite is stored as a sized product, not subject to spontaneous combustion. It is not so friable as soft coal and it may be stored in high piles. It flows readily on itself without serious breakage. The method, therefore, which is practically standard with the large operators is the Dodge or similar system in which the coal is stored by conveyors in high piles, flowing down its own slope as delivered from the stocking conveyors and flowing by gravity to reloading conveyors at the base of or below the piles.

Objects of Coal-Handling Machinery

Requirements for satisfactory coal handling, for either storage or daily service are that the equipment be dependable, durable, of low operating cost and power consumption and needing a minimum of attention for operation and upkeep. First cost should not be allowed to overshadow all other considerations. The object of coal-handling machinery is to save expense, promote efficiency and eliminate interruptions. These are more important than cheese-paring saving in the investment. Above all the installation should be planned to avoid hand shoveling, which is the most expensive possible way of handling coal.

Large plants, which use great quantities of coal can well afford to install complete and elaborate equipment, a duplicate or alternate system being advisable to avoid shut downs.

For medium size plants, a single and less elaborate system will serve with sufficient overhead bunker capacity to tide over short emergencies.

In small plants, only a partial system may be justified but flight conveyors for short runs and portable loaders and unloaders will be found a good investment in even the smallest plants.

Coals which break down easily in handling should be carried to destination rather than dropped and coals liable to spontaneous combustion should be piled with equipment which ensures the most favorable conditions to avoid heating of the piles.

Discussion of the various types and details of equipment is to be given in succeeding articles.

In conclusion, the storage of coal adds to its ultimate cost and the minimum amount is, therefore, a desideratum. On the other hand, this can be offset by storage in such quantity during off seasons as to enable continuity of mining operations. To this end, all consumers can well make some proportionate contribution. And

finally, sufficient amount must be stored and in such places as shall ensure the uninterrupted service of public utility companies and railroads and a reserve for domestic supply against curtailment of production and transportation incident to unforeseen and unavoidable causes. Local considerations influence this greatly; Philadelphia, Pittsburgh or Cincinnati obviously being much more favorably situated in this respect than Boston, New York or St. Paul. One thing that is encouraging is the growing appreciation of the fact that strikes, regardless of the outcome, inevitably entail a heavy loss to labor, capital and the public and will tend to become less frequent. This, with the noticeably increasing efficiency of our transportation systems and of the combustion of the coal itself, will materially affect the amount of storage necessary as an emergency safeguard.

Coal Unloading Methods at Power Plants

MECHANICAL UNLOADING EQUIPMENT IS AVAILABLE FOR EVERY RECEIVING CONDITION MET AT POWER PLANTS

WHEN THE PROBLEM of unloading coal at a power plant is confronted, the general conditions that must be determined before the type of equipment for handling the coal can be decided upon are: How will the coal be delivered to the plant? What sizes of coal will the equipment be called upon to handle? At what rate must the coal be handled; that is, what should be the capacity of the equipment? To what must the unloading device deliver?

For nearly every case of coal unloading, a choice may be made from among a large number of devices which are radically different from each other, so that no definite standard has been adopted for general use and each plant should be considered according to its immediate surroundings.

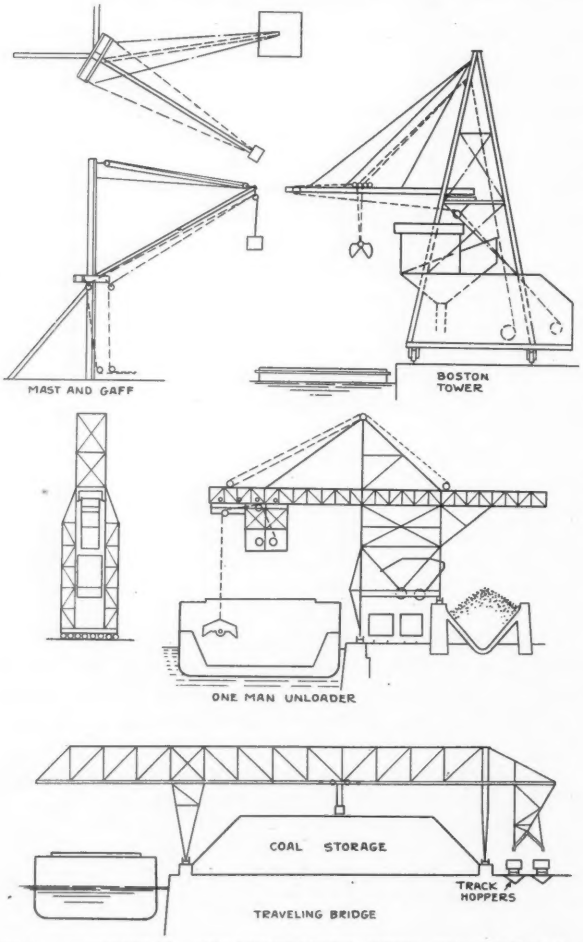


FIG. 1. SEVERAL ARRANGEMENTS USED FOR UNLOADING COAL FROM BARGES DOCKED AT THE POWER PLANT

UNLOADING COAL FROM BARGES

Plants so situated that they can get their coal delivered by barges usually specify this means of delivery as the price is, as a rule, lower than when delivered by cars. To unload barges, however, the equipment employed may be quite different from that which would be used if all coal were delivered in cars. On the other hand, if all coal is sure to come to the plant in barges, only one source needs to be considered. Several arrangements in which a grab bucket is used to unload the coal from a barge to the hopper are illustrated in Fig. 1.

Having simplicity as its principal advantage, the mast and gaff arrangement finds application in some plants. As usually installed, it is driven by a hoisting engine or two motors of the crane type. When worked to capacity, such an arrangement will unload from 50 to 60 t. an hour, but it is limited to boats not over 25 to 30 ft. wide.

Where greater capacity is required, the unloader known as the Boston tower is sometimes used, the capacity being from 75 to 300 t. per hour, depending upon the size of the bucket which is rarely over 2 cu. yd. Two men are required for operating this tower, one to control the raising, lowering, opening and closing of the buckets; the other to control the movement of the trolley on the boom. This tower may be designed to run on tracks on the wharf parallel to the slip and deliver the coal through a hopper to almost any point of the coal conveying equipment.

When more flexibility in delivery is desired, or when coal may come to the plant in cars as well as in barges, a one-man unloader, such as shown, has advantages. This consists of a steel frame tower, carrying a self-contained hoisting unit, or man trolley, which may be moved along the boom. Unloading towers of this type are built with capacity ranging from 100 to 1000 t. per hour, the size of the buckets ranging from 2 to 10 t.

Similar principles are involved in the construction, arrangement and operation of the more elaborate systems for coal unloading from barges which employ traveling gantry and bridge cranes of various types delivering to the conveying system or yard storage. In these systems, the grab bucket is an important detail as the capacity of the system depends quite largely upon the amount of coal the bucket will hold, the rapidity

with which it can be filled and emptied and the completeness with which it can empty a barge.

In Fig. 2 are shown the essential features of several types of grab buckets, which are suitable for coal handling.

These grab buckets are limited as to the sizes of coal which can be handled by the size of the opening of the bucket which varies in different sizes from 51 to 150 in.

Besides those systems which have already been described employing grab buckets for carrying the coal, two other types of conveyors have been used for this purpose in removing coal from barges. These are portable loaders and pneumatic systems. Both of these are of rather recent development and offer possibilities for small plants where the coal comes in sizes that can be conveniently handled by this type of conveyor.

With the barge alongside the wharf and securely fastened, a portable loader can be lowered into the barge by means of a crane and the coal discharged to a portable conveyor, or directly to the coal hopper, if it is conveniently located. This means for unloading barges is quite flexible and with portable conveyors the coal can be discharged considerable distance from the wharf. The portable conveyor can also be used for reclaiming the coal from storage. With this type of unloading equipment, the coal is discharged continuously.

Pneumatic systems of handling coal have been recently developed and are finding application in the smaller power plants of the country. They are likely to give difficulty in handling sizes larger than nut coal. Pneumatic systems are operated either by a vacuum created by an air exhauster or air pump, the coal being delivered to a cyclone head, or the coal is drawn into the inlet head by means of a steam jet which delivers to a hopper or storage.

Methods of Unloading Coal from Cars

When coal is to be delivered to the power plant in railway cars, it is advisable to specify that it be loaded in gondola cars, which are more convenient than box cars, which are seldom used at the present time for this purpose. It so happens, however, that there are two different types of gondola cars, the unloading of which may necessitate some difference in the type of equipment used for this purpose. These are the flat bottom

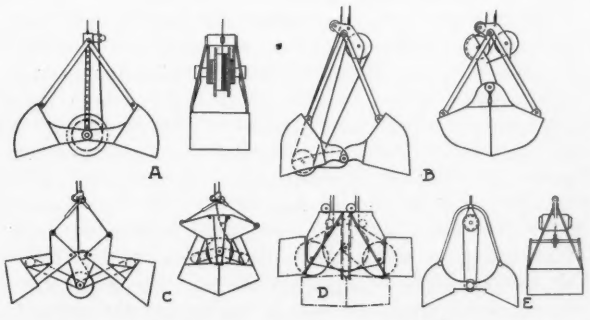


FIG. 2. GRAB BUCKETS USED FOR UNLOADING COAL

A—Bucket closed by drum winding up chain. B—Closing rope passes over bend sheave in head and tightening closes bucket. C—Closing accomplished by winding drum. D—Four ropes required to operate this bucket, which has scraping motion. E—Electrically operated bucket swung from crane hook.

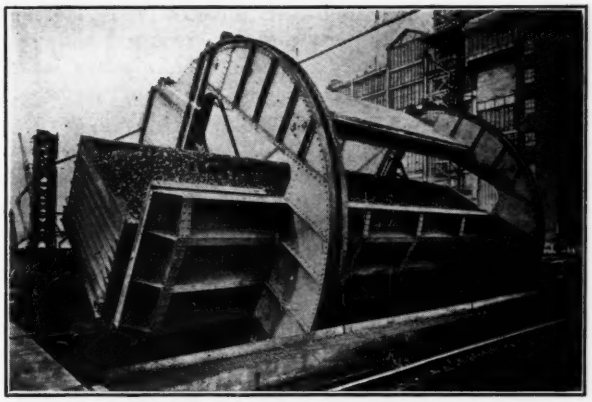


FIG. 3. REVOLVING CAR DUMPER HANDLING STANDARD GAGE RAILROAD CAR

gondolas and hopper bottom gondolas, which are also known as self-cleaning.

For unloading the flat bottom gondolas, the most commonly applied method is by means of grab buckets operated from overhead cranes which may be of the traveling, cantilever or locomotive type. Another method, however, which is coming into practice in the larger plants is by means of car dumpers, which, by mechanical means, turn the car upside down and thus discharge its entire contents in one operation. What is known as the rotary power dump is being built for standard gage cars with capacities up to 120 t. A platform is moved against the side of the car to support it when turned over and hooks are engaged with the top of the car. Both the platform and the hooks are so adjustable so that they can be used with the smaller or larger gondola cars. The frame is rotated by gearing from a motor and the coal is discharged to a hopper below the level of the rail.

Unloading may also be done by means of the pneumatic system which was mentioned in connection with unloading barges, but here again the system is limited to sizes below nut coal.

Hopper bottom gondolas are probably the most popular for delivery to power plants of moderate size, as by this means the coal can be automatically discharged from the car to a track hopper which feeds the conveying system, or, in many cases, the cars are run on

FIG. 4. PORTABLE BELT CONVEYOR DELIVERING TO STORAGE

elevated tracks and discharged directly to the storage area. By this means, no power is required and unloading is done rapidly. If, however, a plant lacks either of these facilities, one of the many forms of portable unloaders may be employed to discharge the coal either to a hopper or to a portable conveyor, which gives flexibility of arrangement in handling the coal.

Power plants so situated that they receive their coal in mine cars directly from the coal mine, usually find it most convenient to employ some form of car dump which discharges directly to a storage bin or to a conveyor system. For this purpose, three types of devices are available. These are the cross-over and horn

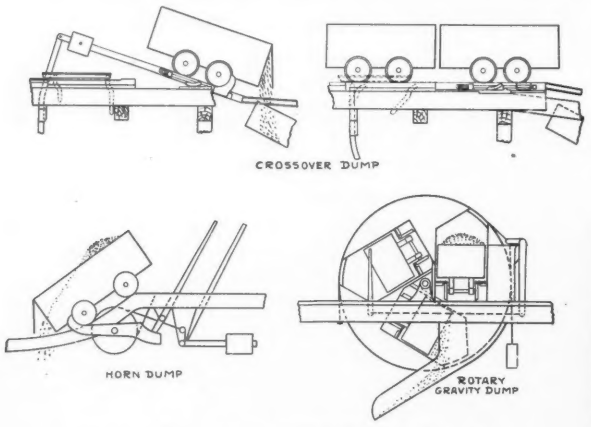


FIG. 5. METHODS OF DUMPING MINE CARS

dump, used to unload mine cars with swinging end doors, and rotary car dump for mine cars without doors. These different kinds of car dumps are illustrated in Fig. 5.

Unloading Coal from Trucks

Where power plants are so located that they must have their coal delivered in trucks, provision should be made for having the unloading done at the most convenient place; in some cases this would be in the storage yard; in others, into coal hoppers and in city office buildings, the coal should be discharged directly through chutes to the storage bin. Two types of trucks are commonly used for delivering coal, one of these being the end dump type which is suitable for all sizes of coal, and the other is provided with coal gates and chutes which may discharge from the side or the end of the truck. Trucks of this type are limited as to the size of coal which they can handle.

Portable loaders which have been mentioned in connection with unloading of barges and hopper bottom gondola cars have a variety of applications and are extremely flexible in their use. They consist essentially of a conveyor from 24 to 30 ft. in length which may be of the belt type or the chain type, mounted on wheels fitted with a receiving boot and discharge chute. The conveyor may be driven either by an electric motor or by means of a gasoline engine. When used for unloading cars of the hopper bottom type, an extension is attached to the end of the conveyor, which extends horizontally under the car and receives the coal from the hopper, discharging to the boot of the loader, thence to the point of delivery.

Receiving Hoppers

In the design of the coal handling system, considerable attention should be given to hopper proportions and size of the track hoppers which receive the coal from the cars, as considerable inconvenience can be caused if these are not properly designed for the need of the plant. With this may also be considered the means for discharging the coal from the hopper to the conveying or preparing systems of the plant.

It is usual to locate these hoppers below the track girder so that any girder may be used or slight changes in track alinement may be made without requiring special fitting of the hopper. The discharge of the hopper should be so designed as to make possible connection with self-contained feeders to the conveying system.

For satisfactory unloading of railroad cars, a 12-ft. width at the base of the rail elevation is the practical minimum with 12 to 18 ft. length for hopper bottom or other cars that can be operated one-half at a time, and 24 to 40 ft. for cars that must be opened over their full length. The hopper width at the bottom of the

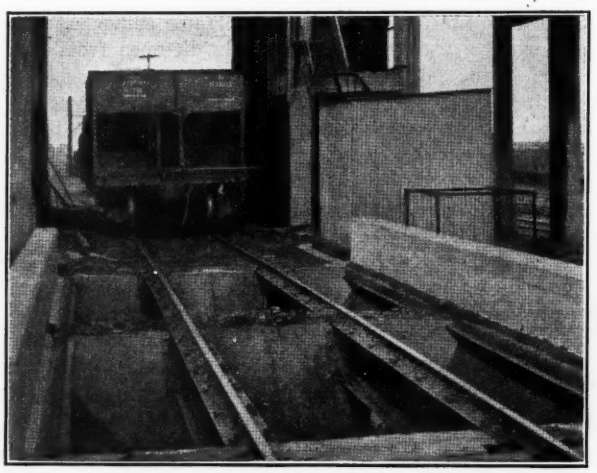


FIG. 6. TRACK HOPPER FOR RECEIVING COAL

track girders must be sufficient to pass maximum lumps between hopper slope and girder flanges, a 10-ft. hopper being about the minimum for 12-in. lumps. Use of bar grate with opening suitable for the equipment fed by the hopper is recommended for protection against oversize lumps or foreign material such as occasional car stakes or mine props.

Coal shipped in the winter time is most likely to come to the plant frozen to such an extent that considerable difficulty may be experienced in unloading it with grab buckets or by gravity and for this reason it is sometimes essential to provide means for thawing this coal out before it can be handled by the conveying means at hand. In some plants it is the practice to run the coal cars into the basement of the boiler room where they are allowed to stand until thawed out. In other instances steam lances have been employed for this purpose, the lances being driven into the coal at several points until the coal is thoroughly thawed out. Another means has been to wet the coal with hot water, just before it is desired to unload it, but this method has some objections as it may put the coal in such condition that it cannot be handled readily.

Power Plants Utilize Many Types of Conveyors

DISCUSSION OF USE AND ADVANTAGES OF VARIOUS TYPES, WITH DETAILS OF THEIR APPLICATIONS TO VARYING PLANT CONDITIONS

CONFINING our consideration in this article only to the conveyors used for handling coal in the power plant, we find a wide variety of practice. While there have been few new principles discovered in the conveying field in recent years, there have been many refinements in mechanical design and construction. The result is that modern conveying machinery, when properly designed and properly applied to fit conditions, is rugged, compact and dependable.

Among the primary considerations that determine the type of coal handling equipment to be used in a given plant is the question of whether or not the coal and ash are to be transported by the same equipment. Certain types of equipment will do this, while certain others are not so well suited to it. At the same time, there is the consideration as to whether or not it is advisable from the operating viewpoint to handle coal and ash with the same conveyors. While it is often considered inadvisable both by operators and designers to do this, here again economic considerations often modify the problem. Another factor that often influences the layout is the type and location of crusher or coal breaker used, which is usually the first piece of equipment in the coal handling sequence.

INFLUENCE OF STORAGE FACILITIES ON CONVEYORS

Then, too, there is the question of the relation of the coal storage pile or coal unloading point to the boiler house. In laying out a new power plant, it is possible in most cases to secure the proper arrangement for direct delivery. But, in remodeling work, especially in some types of industrial plant boiler houses, buildings or other structures may intervene between the unloading point and the boiler room to complicate the problem. In such cases, careful thought should always be given to the advisability of changing the unloading or storage point to provide better conditions and to simplify the coal handling equipment, thus lowering its overhead and operating costs.

Storage facilities for coal and ash also influence the type of equipment that is to be installed in a given case. That is, it may sometimes be necessary to store coal entirely inside the boiler plant, because of lack of outside storage space. Also, it is often desirable to store ash, removed by suitable conveyors, in some sort of a bunker, which can discharge by gravity to trucks or railroad cars for removal from the premises. In some cases, as in boiler plants of hospitals, hotels and buildings located in cities, the ash bunker must hold three or four days' ashes and the coal bunkers a much larger amount to care for emergencies.

All these considerations, therefore, with several others, both tangible and intangible, engineering and economic, have their influence in determining the type of coal handling equipment to meet a given set of conditions.

One of the common types of coal conveyors in use at present is the bucket conveyor. This is often used for elevating coal to bunkers after it has been crushed. It consists of buckets fastened securely to single or double chains running on sprockets or riveted to belts. As can be seen, with these fixed buckets, centrifugal force is depended on to throw the material clear of the buckets when they turn over at the top. On continuous bucket elevators, buckets are spaced close together and arranged so that the back of each bucket acts as a discharge chute for the following one.

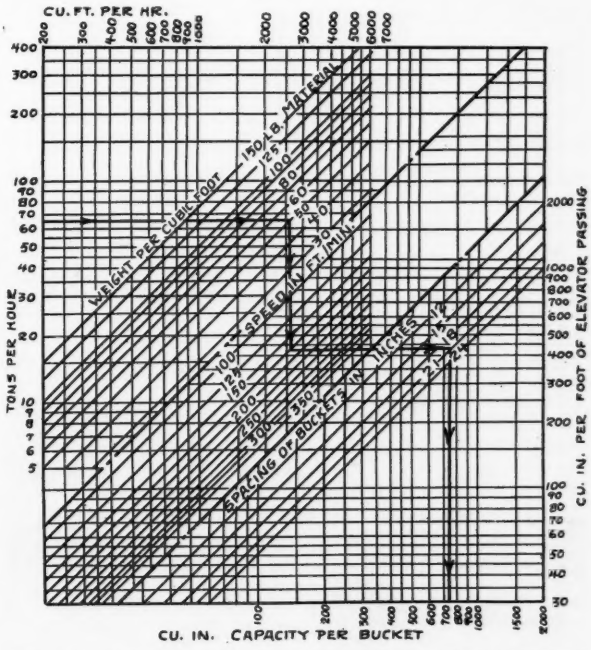

CU. FT. PER HR.
TONS PER HOUR
CU. IN. PER FOOT OF ELEVATOR PASSING
CU. IN. CAPACITY PER BUCKET
WEIGHT PER CUBIC FOOT
SPEED IN FT. PER MIN.
SPACING OF BUCKETS IN INCHES

FIG. 1. CAPACITY AND SPEED CHART FOR BUCKET ELEVATORS. THE HEAVY LINE GIVES THE SOLUTION FOR 65 T. OF COAL AN HOUR AT 175 F.P.M. AND 21-IN. SPACING, SHOWING REQUIRED BUCKET CAPACITY OF 740 CU. IN.

CAPACITIES OF BUCKET ELEVATORS

Capacities of continuous bucket elevators depend on driving speeds which vary from 100 to about 350 ft. per min. with some types. The chart given in Fig. 1 can be used to find the proper size of elevator for a given tonnage or volume of material per hour and a given weight per foot. Dimensions of buckets are usually made larger than the theoretically correct size for a given quantity to allow for lumps and other practical conditions. It is common to assume the working capacity as ⅔ or ¾ of the total capacity when elevators are vertical.

Figure 2 shows a typical elevator installation loading to a storage silo; from the live storage bin in the silo the coal is chuted direct to the stokers in the boiler house. The live storage hopper can be refilled of course, by discharging the contents of the silo to the bucket elevator. Figure 3 is an exterior view of another similar

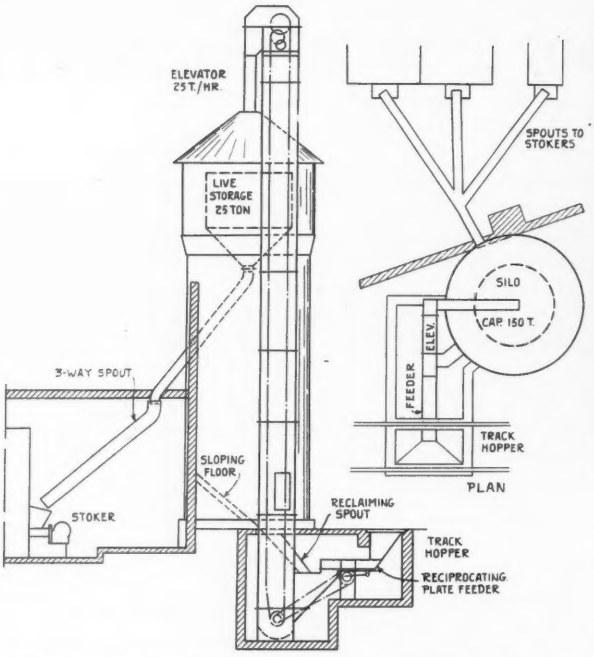


FIG. 2. BUCKET ELEVATOR LOADING SILO; FROM LIVE STORAGE HOPPER COAL SPOUTS DIRECTLY TO STOKERS

arrangement, coal being taken by the larry into the boiler house.

While the bucket conveyor is often used for elevating coal, vertically or at an incline, it is not applicable to horizontal runs. The pivoted bucket elevator and

FIG. 3. THIS TILE SILO IS FILLED BY BUCKET ELEVATOR, COAL BEING REMOVED WITH A LARRY

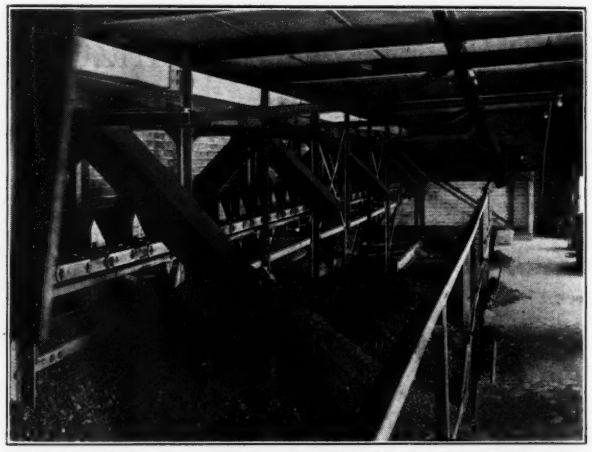


FIG. 4. GRAVITY DISCHARGE CONVEYOR DISCHARGING LIGNITE TO SUSPENDED BUNKERS

the gravity discharge conveyor, however, are designed for both elevating and conveying horizontally.

In the gravity discharge conveyor, a series of V-shaped buckets is mounted between two strands of chain. When traveling vertically, the buckets remain upright and carry the coal but when traveling horizontally they are turned on their sides and run in a trough or trench, scraping the coal along, Fig. 4. In this position, they resemble a flight conveyor and discharge through gates in the bottom of the trough. Because of the friction in the bottom of the trough, these conveyors are usually limited to short horizontal distances.

Uses of the Pivoted Bucket Conveyor

For considerable horizontal and vertical distances, the pivoted bucket conveyor is often preferred. This conveyor has overlapping buckets, travels usually about 40 ft. per min., is quiet in operation and suitable for moderate lifts and capacities. Buckets are in an upright position at all times except when dumping and the chains are carried on suitable wheels running on rails. In some types, the bucket turns clear over when dumping. Pivoted side arm extensions permit the buckets to clear the sprockets when the direction changes from horizontal to vertical. Traveling trippers invert

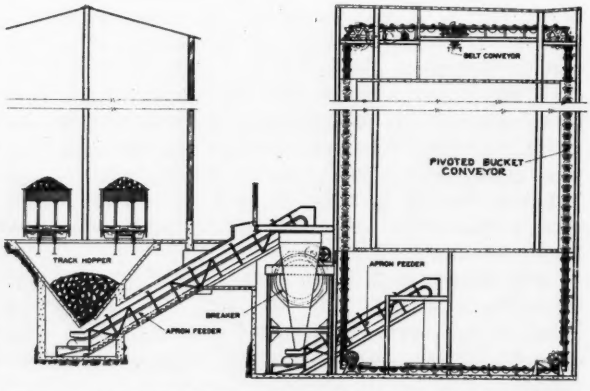


FIG. 5. ARRANGEMENT OF COAL BREAKER, APRON FEEDER, PIVOTED BUCKET CONVEYOR AND DISTRIBUTING BELT CONVEYOR IN A LARGE CENTRAL STATION

the buckets at any desired point, while V-shaped overlapping lips prevent pieces of coal from being carried around and dropped at corners. Skirt boards are provided at loading points, when running horizontally the buckets with their overlapping edges present a practically continuous surface through which coal cannot drop.

Both types of gravity discharge conveyors are in extensive use, usually for capacities of 50 t. as shown or more. They must, however, run in the same vertical plane, so the conveyor is generally run longitudinal with the coal bunkers and discharges directly into them. Where this is not possible, the coal is transferred to a distributing conveyor, Fig. 5.

Drag and Flight Conveyors

The drag conveyor consists simply of a heavy flat chain drawn along the bottom of a trough. Extending

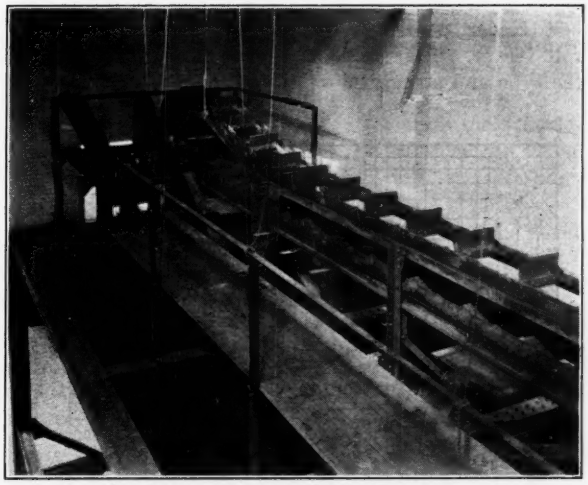


FIG. 6. TYPICAL FLIGHT CONVEYOR INSTALLATION

this principle further, the flight conveyor, Fig. 6, is made by fastening steel flights or vertical plates to the chain to aid in dragging the coal through the trough. One or two chains may be used and these are usually supported on rollers or skids. Flight conveyors are adaptable to longer distances than are the simple drag conveyors; they may be used on inclines up to 40 or 45 deg. When handling coal or ash the abrasive action may be considerable, hence designs have been made with renewable bottoms for this service.

Screw or Spiral Conveyors

Small coal is often distributed to bunkers by screw conveyors; they are also used sometimes as transfer conveyors between different parts of systems. In certain plants burning pulverized coal, they have been used for handling raw coal in the preparation plant, after it has been delivered to the storage bunker by some other type of conveyor. They have also been used for handling pulverized coal from the mills to the bunkers supplying the feeders or burners in the central system.

For coal, screw conveyors range in diameter from about 9-in. handling about 15 t. an hour of coal not over 1 in. in size to 16 in. in diameter handling about

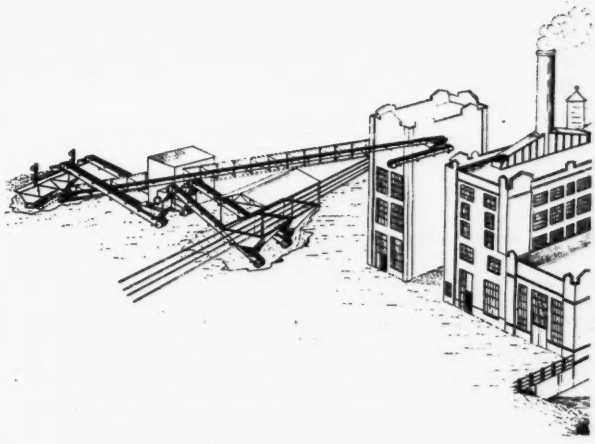


FIG. 7. BELT CONVEYORS TAKING COAL ON INCLINE TO PREPARATION PLANT OF A CENTRAL STATION

75 t. an hour. One of their principal advantages is their compactness, as there is no return strand.

Cable conveyors, consisting of circular discs on clamps mounted on a steel cable and dragged through a steel trough have been used for handling coal in a manner similar to the flight conveyor.

Use of Belt Conveyors

For handling coal, especially in some of the larger power plants, the belt conveyor has become of increasing importance, as it has been developed to convey large quantities at extremely long distances. Although it usually runs horizontally, it can be arranged on inclines up to 18 deg. for handling coal, as in Fig. 7. By means of traveling trippers, Fig. 8, the belt can be unloaded at any point of its travel or the coal can be discharged over the end. In many cases, a short shuttle conveyor mounted on trucks replaces the tripper; in this event, the main conveyor discharges over the end of the belt to the shuttle which is moved to such a position that it discharges over its end in turn at the desired point. The object of this arrangement is to eliminate the double reversal given the belt in a tripper.

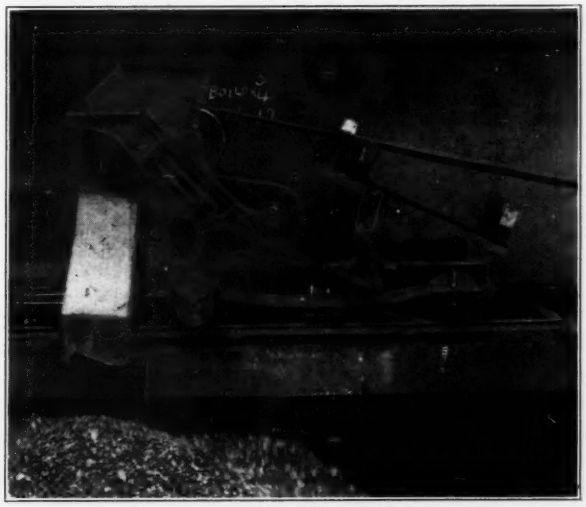


FIG. 8. SELF-PROPELLING, SELF-REVERSING BELT TRIPPER ON BELT CONVEYOR

Belts are supported on three or five troughing idler pulleys, giving a troughed or arced section while the returned or unloaded part of the belt runs back on a straight idler.

Capacity and Speeds of Belt Conveyors

Width of belt depends on size of lumps to be handled and capacity desired. One designer states that the

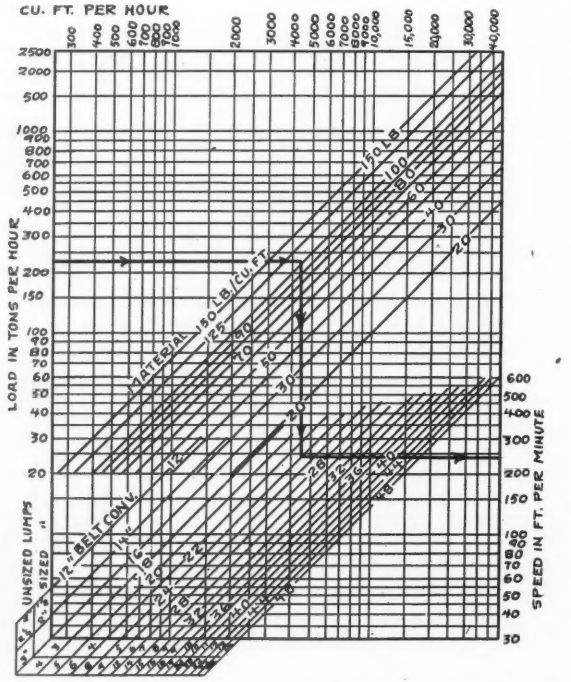


FIG. 9. CAPACITY AND SPEED CHART FOR BELT CONVEYORS. ARROWS SHOW SOLUTION FOR 225 T. AN HOUR, 8-IN. LUMPS WEIGHING 100 LB. PER CU. FT. A 24-IN. BELT IS NEEDED RUNNING 240 F.P.M.

width should be at least four times the uniform size of material handled plus 6 in. or four times the average sized pieces plus 6 in. when such pieces are about 70 or 80 per cent of the whole and in no case less than twice the largest pieces plus 8 in. where such pieces do not exceed 10 per cent of the material. This rule provides therefore for belts 14 in. wide for material containing 2-in. lumps under the above conditions, up to 48 in. belts for material containing 10½-in. lumps or 20-in. lumps if they do not exceed 10 per cent of the total.

While use of anti-friction bearings on belt conveyors increases the cost of the conveyor as a whole, power consumption is greatly reduced, usually to about 60 per cent of that required with plain bearings and the use of anti-friction bearings has other advantages that have led to their extensive application. Advisability of using them should be determined in each individual case, considering first costs and power requirements.

Charts useful in figuring capacities and horsepower of belt conveyors are shown as Figs. 9 and 10.

Portable conveyors of the above mentioned types—such as belt, flight, and bucket—have been developed for various uses such as unloading cars to storage or to bins not located directly below the track, feeding a fixed conveyor or elevator from a variable point such as the face of a storage pile, and so on. They usually range in length from 15 to 30 ft. and some types handle, in the larger sizes, 40 to 60 t. an hour. They can be used inclined at an angle up to about 20 deg. and often replace hand shoveling operations at a much lower cost.

Feeders for Conveyors

For feeding coal to conveyors and coal crushers, whose effectiveness would be impaired by overloading, various feeding devices are necessary to coördinate the flow of coal with the speed of the conveying system. They are especially needed when the material contains lumps, as the passage of the lumps through a gate would be accompanied by a surplus of the finer material. The feeder is designed to measure out the material at the exact rate at which the following machine can take it, not only preventing overload but maintaining the full load rate of the following machine. The four principal types of feeders used with modern coal conveyors are: belt feeder, steel apron feeder, reciprocating feeder, roll feeder. There are, of course, many variations in the type and structural details of these.

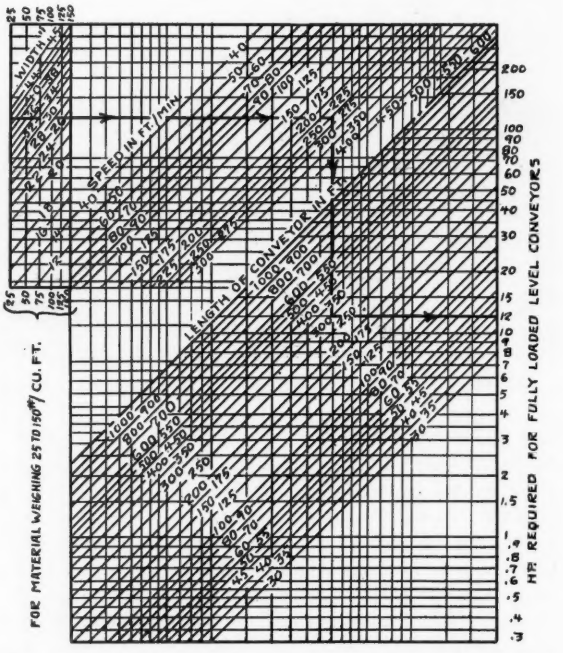

WIDTH IN INCHES
SPEED IN FT./MIN.
LENGTH OF CONVEYOR IN FT.
FOR MATERIAL WEIGHING 25 TO 150# CU. FT.
HP REQUIRED FOR FULLY LOADED LEVEL CONVEYORS

FIG. 10. HORSEPOWER CHART FOR BELT CONVEYORS. ARROWS INDICATE SOLUTION FOR LEVEL, FULLY LOADED 36-IN. CONVEYOR, 300 FT. LONG, MATERIAL 50 LB. PER CU. FT. AT 250 F.P.M. THIS WILL REQUIRE 12 HP.

Before leaving the subject of belt conveyors, mention should be made of the type using a flexible steel belt instead of a fabric or rubber belt. These belts are carried flat on steel rollers. For unloading them, a plow, mounted on wheels so it can be moved along over the belt scrapes the coal off on both sides.

Conditions are not always suitable for the use of a monorail, but when they are, it is a convenient and simple method of reclaiming coal to the boiler house. The monorail consists usually of some sort of traveling bucket or hopper on one or two rails, with operator's control cab mounted on the traveling carriage. There

have been installations in which the monorail was loaded outside the plant and run in to fill the coal bunkers, or was equipped with a grab bucket which picked up coal from a storage pile. Such an installation requires considerable headroom over the bunkers. In other cases the monorail has been discharged directly into hoppers of stokers or pulverizers on which it becomes practically a larry, which will be described later.

Pneumatic Methods for Handling Coal

Pneumatic methods of handling raw coal—not pulverized coal—have received considerable attention, especially for applications requiring several changes of horizontal and vertical direction, where mechanical equipment has a tendency to become somewhat cumbersome owing to the necessity of one conveyor discharging to another.

In one pneumatic system recently installed, coal and air enter a cyclone in which a suction of 7 to 10 in. of mercury is maintained by a motor driven exhauster. In the cyclone, the centrifugal action permits the coal to settle to the bottom onto a feeder which transfers it to a bunker. Air leaving the top of the cyclone passes through a washer and out through the exhauster. Coal is carried to the cyclone from a coal car through a flexible hose and a pipe supported on a swinging boom so that it can reach any part of the car. With this equipment a 50-t. car of slack has been unloaded in 3 hr. with an expenditure of 42 hp. or about 2½ hp-hr. per ton.

Lubrication of conveying machinery merits much more consideration than it usually receives. Possibilities of reducing power consumption by use of the proper lubricants are frequent. Constant improvements are being made in methods of applying lubricants—pressure methods of applying grease through special fittings with a gun, for example.

Conveyor Drives

Methods of driving conveyors are beyond the scope of this article. In general, electric motors are used owing to the many advantages they possess in compactness, ease of control and general adaptability to this work.

Mention should be made, of course, of the electrical interlocking systems now available to insure operation of conveyors in proper sequence. That is, the electrical starting and stopping devices for the driving motors are interlocked in such a way that no particular element of the conveyor system can be started until the elements following it are in operation or conversely so that the stopping of one element shuts down all the others. For example, with such an interlocking system, the conveyor over the bunkers must be started first, next the elevator feeding it must be started, next the crusher or feeder loading the elevator.

Motors drive the conveyors, as a rule, through some sort of gearing to secure the proper conveyor speed. This is often spur gearing with suitable brakes, locking devices to prevent conveyor runback and so on. Speed reducers of spur gear, worm gear and herringbone gear types have found many applications in this work.

Several of the accompanying illustrations show layouts of actual conveyor installations in several types of large and small industrial power plants and central stations.

Crane Systems for Coal Storage

Description of Various Types of Bridges and Cranes. Uses and Particular Adaptations of Each Type

BRIDGE CRANES are of the Gantry type, that is, they are traveling cranes equipped with grab-buckets and whose lifting device is set high in the structure so as to clear coal which may be piled high between its two supports, while the crane itself travels on rails on ground level. Bridge cranes are used to unload coal from open-top freight cars and barges or ships and place it in open storage piles; also to reclaim such coal from these piles and deposit it on conveyors or other coal handling means for transference to power station bins.

Classification of Bridge Cranes

Cranes of the bridge type may be divided into four classes according to the method of handling the coal on the bridge, as follows:

1. Rope trolley, in which the bucket is operated from a stationary house on the bridge.

2. Man trolley, in which the bucket is operated directly from a moving cab. Buckets holding as much as 12 t. are used on this type.

3. Belt conveyor type in which the bridge serves as a support for a belt conveyor which, by means of an automatic trip, dumps the coal at any desired point.

4. Cable road bridge on which a car runs. Small side dump cars pass from a track running lengthwise of the storage yard upon the bridge from which they are dumped. The coal is reclaimed by a clam shell bucket operated from the same bridge.

Grab Bucket Size and Speed Limit Capacity

Capacities of bridge cranes are limited by the size and speed of the self-filling grab-bucket usually carried by them. These buckets are from 2 to 10 t. The span of bridge cranes varies with local conditions. Some are made as much as 500 ft. from center to center of the supporting towers. The span is constructed of trussed steel and is usually provided with a cantilever at one or both ends, as required by local conditions. Some of the larger sizes have all of the drums for the control of the bucket mounted, together with the operator's cab, on the trolley. These "man-trolley" bridge cranes are very fast in operation and give high capacities. Hoisting speeds range from 5 to 85 ft. per min. and bridge speeds from 100 to 350 ft. per min., according to size.

When used for unloading coal from vessels, the cantilever end is hinged so that it may be raised to clear

the masts of vessels and be housed inside of the dock lines. The bridge span is flexibly mounted on the supporting towers to prevent distortion should one end run ahead of the other.

Bridge Crane Drives

Bridges are propelled in various ways, the most usual drive consisting of motors geared to the truck-

FIG. 1. BRIDGE CRANE WITH 142-FT. SPAN AND 28-FT. OVERHANG AT ONE END IS EQUIPPED WITH 2½-CU. YD. BUCKET

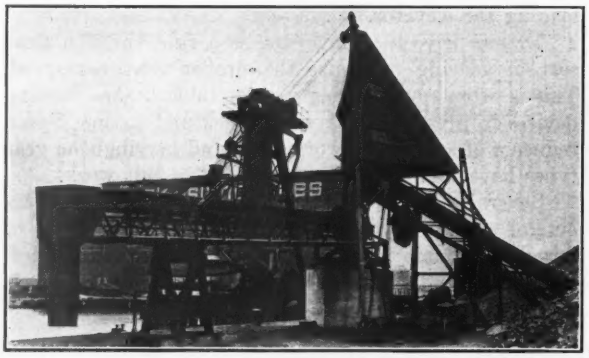


FIG. 2. BOOM CONVEYOR IS EQUIPPED WITH TELESCOPIC CHUTE TO PREVENT FINE MATERIAL FROM BEING CARRIED AWAY BY WIND

FIG. 3. STACKER IS MOUNTED ON RAILWAY FLAT CAR AND EQUIPPED WITH 6-T. HOPPER

wheel axles. Two drum-type controllers are used, each controlling the motors at one end of the bridge. Indicators are provided so that the operator knows the relative position of the two ends at all times and the two controllers enable him to move both ends of the bridge at the same speed. One manufacturer gears the motors to the axles of the truck wheels by worm-gear and spur-gear reductions, the worm-gears acting as an automatic lock when the bridge is stationary. Another manufacturer employs cables anchored at the ends of the bridge travel, passing over motor-driven drums on the bridge trucks. This method pulls the bridge along independent of the friction of wheels on the rails, solenoid motor brakes locking the bridge when not in motion. The two ends are handled by separate controllers.

Capacities of bridge cranes range from 100 to 500 t. per hr. depending upon the size of the buckets and motor equipment. Speeds of bridge traverse range from 50 to 200 ft. per min., depending upon the service. Speeds of man trolleys range from 500 to 1500 ft. per min. On account of the high initial cost of traveling bridges, their use is restricted to the handling of large capacities where the cost per ton of handling justifies the investment.

Rotary Bridges Useful for Circular Storage

Rotary bridges or cranes may be considered as another general class of storing and reclaiming devices that lend themselves particularly well to circular storage although they may also be used for other storage systems. Under this head we may group boom con-

FIG. 4. LOCOMOTIVE CRANE RECLAIMING STORAGE COAL BY DELIVERING IT TO A BELT CONVEYOR PROVIDED WITH A TRAVELING HOPPER TO RECEIVE FROM GRAB BUCKET OF THE CRANE

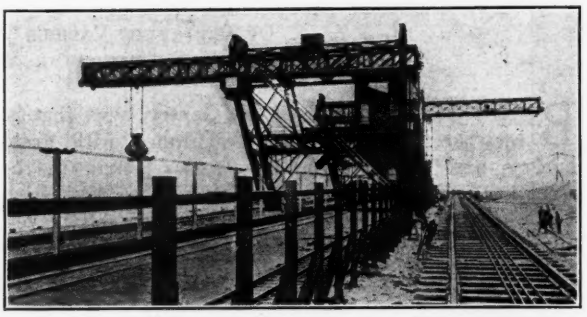


FIG. 5. LARGE CAPACITY TOWER CRANES, EACH OF WHICH HANDLES COAL FROM LAKE FREIGHTERS AT A RATE OF 800 T. PER HR. WITH BUCKETS OF 4½-T. CAPACITY

veyors and derricks, locomotive cranes, tower systems and pivot or swivel bridges. Rotary cranes are used for lifting material and moving it to points covered by a boom pivoted to a fixed or movable structure. Pillar cranes are always fixed and used for light, infrequent service.

Application of the boom conveyor as illustrated in Fig. 2, shows its peculiar adaptability for loading vessels. A telescopic chute is provided at the end of the boom to prevent fine coal from being carried away by wind during the loading operation.

Boom conveyors may also be mounted on standard

railway flat cars such as shown in Fig. 3, which are equipped with a 6-t. hopper and feeder that delivers the fuel to the boom conveyor in whatever position it is used. The boom has a vertical movement of about 45 deg. and a lateral swing of about 90 deg. This particular stacker car is moved about by a gasoline locomotive which carries a generator for supplying power for the hoisting and conveying machinery. Similar stackers are also driven by oil engines directly attached.

Derricks may be made with either wood or steel masts and booms of the guyed or stiff-leg variety and are either self-slewing or swung with a bull wheel. The motive power may be closely connected or remote with a flexible connector.

Motive Power Varies for Locomotive Cranes

Locomotive cranes of the revolving type are generally used for storage except when very large special equipment is necessary. Such cranes are equipped with clam-shell or orange-peel buckets and are powered by steam, gasoline or oil engines or operated electrically. These cranes are self-propelled at the rate of from 4 to 8 mi. per hr. and are controlled by one man. The revolving superstructure is supported on a base which rests on four or eight wheels, the eight-wheeled car body being preferred.

Speed of operation varies greatly with the operating conditions, but generally averages about one bucket per minute. At the coal yards of the Commonwealth Edison Co. a locomotive crane with a 2-yd. clam-shell bucket will ordinarily unload from 10 to 15 cars per day of 8 hr. One operator has loaded as many as 25 cars in 10 hr. The crane can load faster than it can unload cars. Locomotive cranes are adaptable to circular storage systems as will be seen elsewhere in this issue in the discussion on storage systems.

Capacities and Limits of Locomotive Cranes

Locomotive cranes weigh from 40,000 to 130,000 lb. and have capacities ranging, at 10 ft. minimum radius, of 10,000 lb. to that, at 13 ft. minimum radius, of 40,000 lb. and, at maximum radii of from 25 to 60 ft., of from 3000 to 5500 lb. Heights of lift for grab-buckets range from 22 ft. to 17 ft. for corresponding radii of 15 to 50 and lengths of boom of from 38 to 50 ft.

Swivel or radial bridges are probably less economical than locomotive cranes for handling quantities of coal within the capacities of the latter type of apparatus but they can be employed advantageously for larger quantities. Coal may be handled at very little expense by such a bridge where electric power is available. A 280-ft. span radial bridge pivoted at one end and swinging through 360 deg. will store 100,000 t. of coal in a pile 30 ft. deep.

Steeple towers or Cantilever cranes of steel or wood may be used instead of locomotive cranes. These towers may be either fixed or movable. In the latter case, they are usually run on tracks parallel with the river front. The booms are generally arranged so that they may be drawn back when not in use. With a 1½-t. bucket such a tower will unload and deliver to conveyors about 150 t. per hr.

Cantilever cranes are frequently used for unloading from boats and delivering direct to a plant without

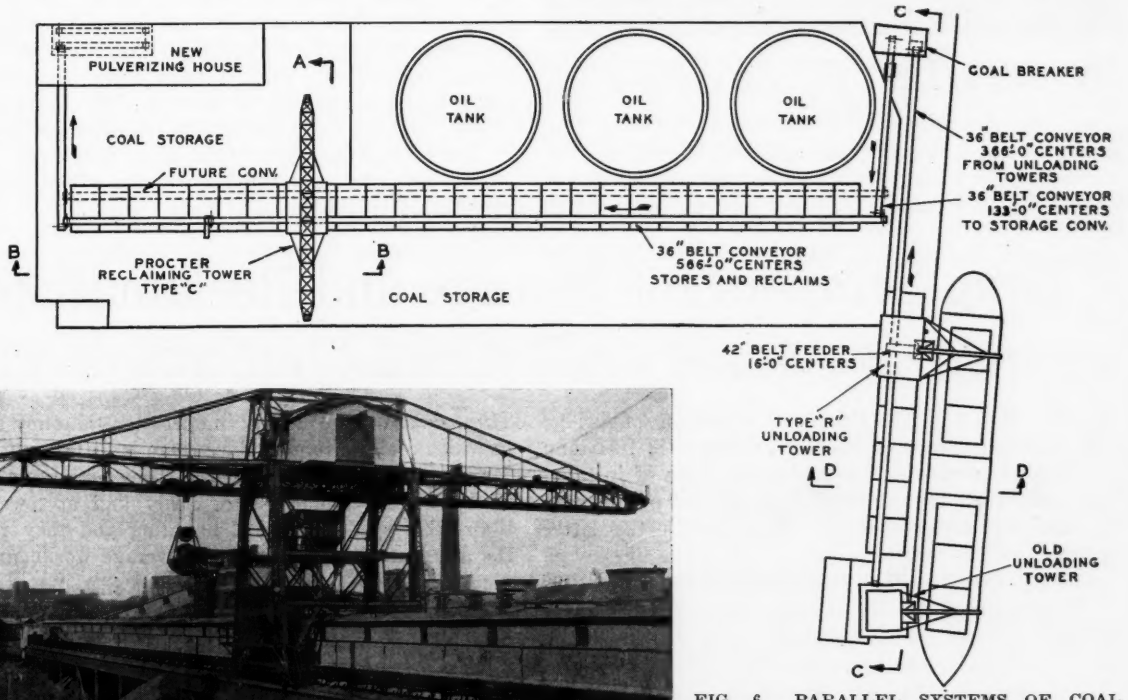


FIG. 6. PARALLEL SYSTEMS OF COAL STORAGE SERVE PLANT WHERE CONDITIONS ARE PECULIAR

FIG. 7. CANTILEVER BRIDGE AT LARGE PLANT SERVES AS PART OF TWO INDEPENDENT STORAGE AND RECLAIMING SYSTEMS

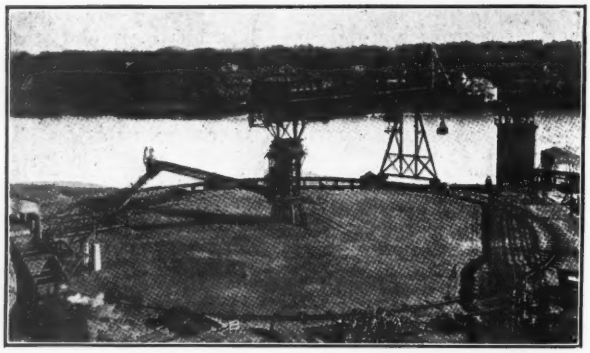


FIG. 8. RADIAL BRIDGE WITH BOOM EXTENDING OVER THE WATER SO THAT COAL MAY BE UNLOADED FROM BOATS

ground storage or with some means of storage and reclaiming other than a bridge. They are usually driven electrically or by steam and are provided with booms on which a grab-bucket trolley is operated. The boom is usually so hinged that it can be folded up vertically or swung sideways to clear masts and rigging of vessels. In some cases, the boom extends through the tower and projects at the back so that material dug from a boat in front of the tower may be stored on the ground or reclaimed from the ground by the grab-bucket.

Two steel frame electric traveling towers of an unusual type in which the hinged boom is replaced by a trussed steel ram that slides in and out through the tower structure and on which the bucket trolley travels as on a boom, are illustrated in Fig 5. The vertical clearance in this case was kept down to allow the cantilever of a traveling bridge to pass over the towers. Unless required by limited head room, this type of tower is not economical, on account of the extra weight of steel and the extra machinery required for the ram.

An interesting application of a cantilever bridge crane serving as a parallel system to a belt conveyor installation is illustrated at Figs. 6 and 7.

Drag Scrapers for Storage and Reclamation

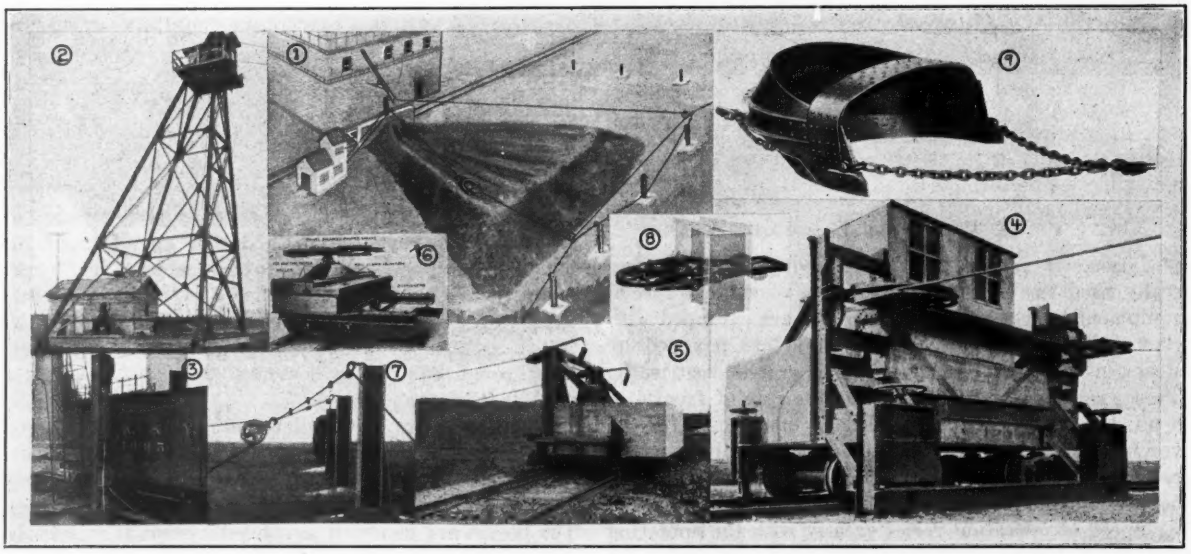
SIMPLICITY OF EQUIPMENT AND OPERATION AND LOW COST OF INSTALLATION ARE PRIMARY FEATURES THAT FAVOR DRAG SCRAPERS FOR COAL HANDLING

ALTHOUGH THE COST of operation of bridge cranes or even of locomotive cranes is less than that of drag scrapers, low initial cost, ease of installation and much greater flexibility and adaptability to irregular storage space are obtained with the latter system.

ADVANTAGES OF DRAG SCRAPER OPERATION

Drag scrapers operate with the same facility up or downhill, on wet, soft or submerged ground. They mix lumps and fines together, preventing air passage and thereby reducing the fire hazard of coal in storage. They are also more cleanly in operation than any system in which coal is dropped since there is little opportunity for wind to carry fine particles. They may be relocated when necessary, much more easily and at lower cost than other systems of coal handling and they require the attendance of only a single average workman.

Upkeep is low with drag scraper installations since the wearing parts of the bucket are renewable and can be replaced at small cost. Many drag scraper installations are in use with the original buckets and engines after 10 yr. of service.



DRAG SCRAPER EQUIPMENT. FIG. 1—TYPICAL ARRANGEMENT FOR SMALL COAL STORAGE YARD. FIG. 2—SELF PROPELLED STEEL HEAD TOWER FREQUENTLY PROVIDED WITH HOPPER FOR RECLAIMING OPERATION. FIG. 3—SMALL HEAD POST. FIG. 4—HEAVY SELF PROPELLED TAIL TOWER FOR STANDARD GAGE TRACK. FIG. 5—MOVABLE TAIL POST WITH CONCRETE COUNTERWEIGHT AND CLAMPS. FIG. 6—TAIL BLOCK CAR WITH CLAMPS AND OUTRIGGING. FIG. 7—TAIL POSTS, BRIDLE AND TAIL BLOCK. FIG. 8—BALANCED TAIL BLOCK. FIG. 9—LARGE CRESCENT SCRAPER BUCKET

Flexibility and simplicity of installation are illustrated in Fig. 1. Drag scraper equipment consists essentially of a head tower or post, a tail tower or post, with bridles, blocks, cable and scraper. Head and tail towers and posts may be either stationary or movable. As the coal is usually drawn to one point, the head post is usually fixed. For smaller installations, stationary tail posts are usually used and the tail block is moved and relocated by means of a bridle as indicated in Fig. 1, the tail block being attached to the bridle or fixed cable running between two tail posts, thus permitting of easier adjustment of its location to any point along the fixed cable. When the area covered by the distance between two posts has been exhausted the fixed cable is moved to the space between two other posts.

Where movable tail towers are used, their limitation in radius of movement on the track restricts them to storage fields having rounded corners. Such towers are, however, especially serviceable for circular or semi-circular fields. Larger sizes of tail towers are self-supporting; smaller sizes require rail clamps or outrigging to provide stability during operation.

Actual handling capacity of scraper equipment should be figured in volume and not in weight, although the handling capacity is usually stated in tons per hour. A given size of scraper will not always handle the same amount of coal because the handling capacity is much greater on short hauls than it is on long hauls. The proper size of scraper equipment should, therefore, be based upon the average distance over which the scraper will operate.

Bucket sizes vary from the ½-t. size to a scraper capable of hauling 4 t. at a time. This gives hauling capacities ranging from 60 t. per hr. to 550 t. per hr. when based upon an average haul of 100 ft. For small capacity, a 25-hp. motor is required and for the highest capacity mentioned, a 200-hp. motor is needed. Cable speeds vary from 350 to 470 ft. per min.

Return speed of the empty bucket is usually higher than the working speed with loaded bucket, thus tending to equalize the power requirements. Usual speeds with small buckets are about 200 ft. per min. loaded and 400 ft. per min. unloaded. Speeds of larger buckets are about 200 ft. and as high as 500 ft. per min. respectively.

Skip Hoists and Larries Find Many Applications

Discussion of Types of Skip Hoists, Methods of Loading and Hoisting, Capacities and Speeds. Uses and Advantages of Weigh Larries

FOR LOADING COAL from track hoppers or storage piles into overhead bins or bunkers in the power plant, skip hoists are often used, especially where the coal contains lumps or where the lift is so great as to make the use of a bucket elevator impracticable. Their applications have been increasing in recent years, owing to their flexibility and simplicity.

In some cases they discharge to conveyors running over bunkers in the boiler room, from which coal is spouted directly to either stoker hoppers or pulverizing equipment. In other cases they load a bin at one end of the boiler room or even outside the boiler house altogether, the coal being distributed to the coal burning equipment within by larries, usually of the weighing type. Several interesting installations of the latter type have been made in which great advantages are claimed because of the freeing of the boiler firing aisle from overhead obstructions, permitting better lighting and eliminating coal dust in the boiler room itself.

Skip hoists consist essentially of four elements: the skip bucket, the hoisting engine, the rope and sheaves, the bucket guides and structure. The hoisting engine winds up a rope which lifts a bucket full of coal controlled by the guides. The lift may be increased almost without limit, at low cost for rope and guides but the capacity will vary in inverse ratio, of course, with the increase in height. The skip hoist may handle either coal or ash or both, depending on plant conditions, and may be vertical or inclined. This dual use of the hoist, however, is not as extensive as that of other types of conveyors.

Skip Hoists Are of Three Principal Types

Three fundamental types of skip hoists are used as shown in Fig. 1. These are the unbalanced type, using one bucket, the counterweighted type, consisting of a single bucket with a counterweight equal to the weight of the empty bucket plus half the load of the material and the double balanced type in which one bucket goes up as the other comes down and the motor load never exceeds the weight of the material in one bucket plus the friction load.

Capacities and Speeds of Skip Hoists

Capacity depends on speed, lift, method of loading bucket size and lift. Speeds vary according to kind of service; average speeds are classified as: slow, about 80 ft. per min., medium about 140 ft. per min., and high about 260 ft. per min. Slow speed hoists, used mostly for ash handling, have buckets of from 20 to 60 cu. ft. capacity, about 10 to 30 t. per hr. based on 80-ft. lift. With automatic loading, standard buckets may range from 40 to 120 cu. ft., giving 110 t. per hr. capacity at 80 ft. lift.

High speed skip hoists for coal have standard buckets of 40 to 120 cu. ft. With single buckets, capacities from 150 t. per hr. are attained, while with balanced buckets they may have 300 t. per hr. capacity at 80 ft. lift. Bucket speeds seldom exceed 300 f.p.m. while, with automatic loading, bucket speeds entering the loading and dumping zones should not exceed 125 f.p.m. In manual loading, this speed should be not over 150 f.p.m.

Loading may be manual or automatic. With manual loading, the coal is usually delivered to the bucket by a workman in a barrow or dump car, dumping it either directly into the bucket or into a feeding hopper with a manually-operated gate. He then starts the winding machine, goes for another load and when he returns the bucket is again in position for loading.

Automatic Loading of Skip Hoists

With automatic loading, coal is loaded into a hopper with a gate that is opened, often by the skip bucket itself, as it comes down into loading position. After the bucket is loaded, the gate, which is properly counterweighted, closes itself. Then, if the hoist is semi-automatic, the operator starts the winding machine and raises the load. With full automatic control, the electrical connections are arranged so that after the bucket is loaded and the loading gate closed, the winding machine starts itself, raises and dumps the load and lowers the car again to loading position, when the cycle is repeated automatically with no further attendance. Figure 2 shows an automatic loading gate and Fig. 3 a typical skip bucket both in lifting position and in position for dumping at the top of the guides.

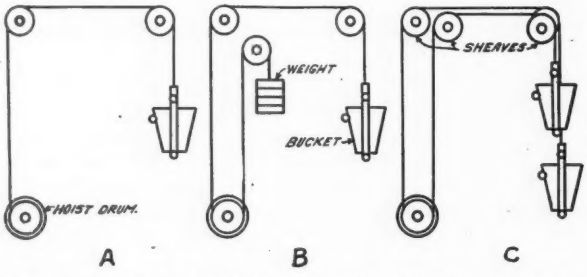


FIG. 1. THREE FUNDAMENTAL TYPES OF SKIP HOIST: A—UNBALANCED TYPE, B—SINGLE BUCKET, COUNTERWEIGHTED, C—DOUBLE BALANCED TYPE

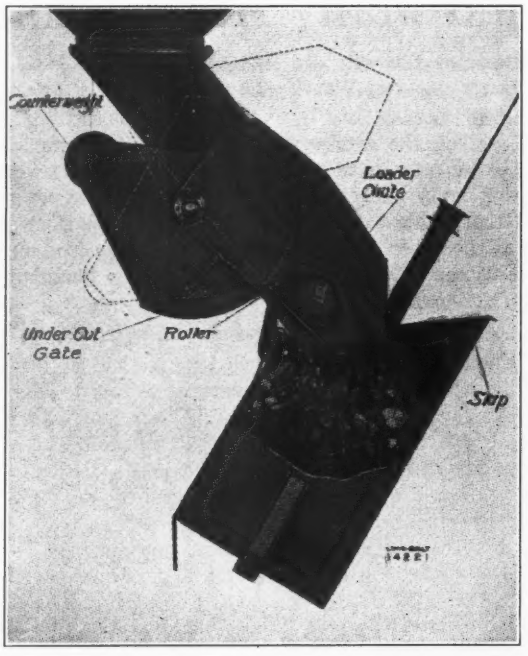


FIG. 2. AUTOMATIC LOADER FOR SKIP BUCKET

Drive for the winding machine is usually by electric motor, which may be of the direct current compound-wound type or of the high-torque squirrel-cage alternating current type. Recent development of a hydraulic valve control is intended to permit driving the hoist by steam or Diesel engine.

One of the most convenient ways of transferring coal from the overhead bunker or bin to which it has been loaded by the skip hoist is by means of a larry.

Use of Larries

Briefly, a larry consists of some sort of a hopper mounted on wheels that run on rails so that the coal can be discharged from the larry directly to the coal burning or preparation equipment. Larries are often of the weighing type in which the hopper is suspended on scales. The scale beam box, in such a case, is usually suspended so it can be read from the firing floor and often an automatic weighing ticket device is used.

Larries are either hand or motor operated. The hand-operated larry has one wheel axle geared to a counter shaft carrying a sprocket wheel operated by a chain hanging down to the operating floor. The motor driven larry is usually propelled by a motor geared to the axle and controlled usually by an attendant riding on the larry. The motor controls may, of course, be by ropes or chains hanging down to the operating floor but this arrangement is not recommended for long travel or high speed.

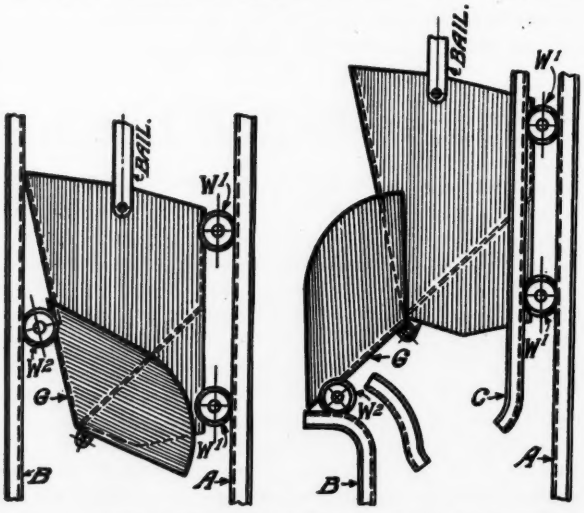


FIG. 3. TYPICAL SKIP BUCKET. LEFT—AS IT APPEARS LOADED RUNNING UP BETWEEN GUIDES. RIGHT—SHOWING HOW GUIDES SPREAD AT TOP TO ALLOW BOTTOM TO OPEN AND DISCHARGE, GATE G ACTING AS THE CHUTE

Larries may be supported on overhead track or may run on tracks in the floor. The overhead track, while requiring more headroom, leaves the boiler aisle free from obstructions and causes little trouble from coal getting on the track, hence it is usually preferred.

Advantages claimed for the larry, whether of the weighing or nonweighing type, are numerous, in comparison with the use of fixed chutes. With the larry, the bunker may be in one end of the building or outside it altogether. If used with an inside bunker, the bunker gates may be spaced close together, leaving a minimum of dead coal even though a flat-bottom bunker is used. With a larry, coal can be distributed evenly across a stoker hopper to avoid segregation of fines, by moving the larry while the coal is flowing. If the larry is of the weighing type, records of coal used by each boiler are available for the performance data, as well as a record of the total. By using a larry, fires in the bunkers (which

are, on the whole, infrequent), may be handled easily by drawing off the burning coal from any section or from the whole bunker and delivering it to the coal-burning equipment.

Capacities of weigh larries vary, the most common being from 1000 to 10,000 lb., although they can be made of any convenient capacity to suit individual needs. The sizes noted, however, will meet most requirements.

Typical Installations

Typical installations of skip hoists and larries are shown in the accompanying illustrations. Figure 4 shows an interesting installation of both. Here coal is loaded by a drag scraper to an automatic skip hoist which fills the steel storage bin that can be seen behind the tile ash-storage bin. A motor-operated weigh larry takes coal from the bin, runs through the enclosure seen below the bin and into the boiler room, where it discharges to three stoker hoppers on one side and on the other side, through a chute to three unit pulverizers in the boiler room basement.

Coal handling arrangements in the plant shown in Fig. 5 are unusual but have given extremely good results. Coal is dumped inside the boiler house from the cars direct to a hopper feeding an automatic skip hoist. This raises the coal and dumps it in either of two directions to fill two overhead bunkers. From these, the weigh larry shown in Fig. 6 conveys it to the hoppers of the unit pulverizers in front of the boilers.

It must not be understood that use of larries is confined only to installations in which the coal is elevated by a skip hoist. They have an important advantage, when used with an overhead bunker over the firing aisle, in that they permit use of coal from any part of the bunker by any of the stokers or pulverizers.

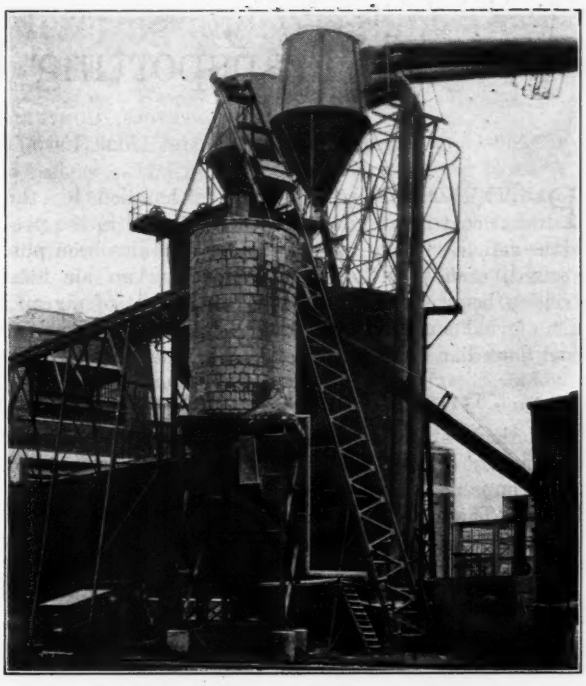


FIG. 4. SKIP HOIST LOADS STEEL BIN OUTSIDE PLANT AND WEIGH LARRY DISTRIBUTES COAL FROM IT

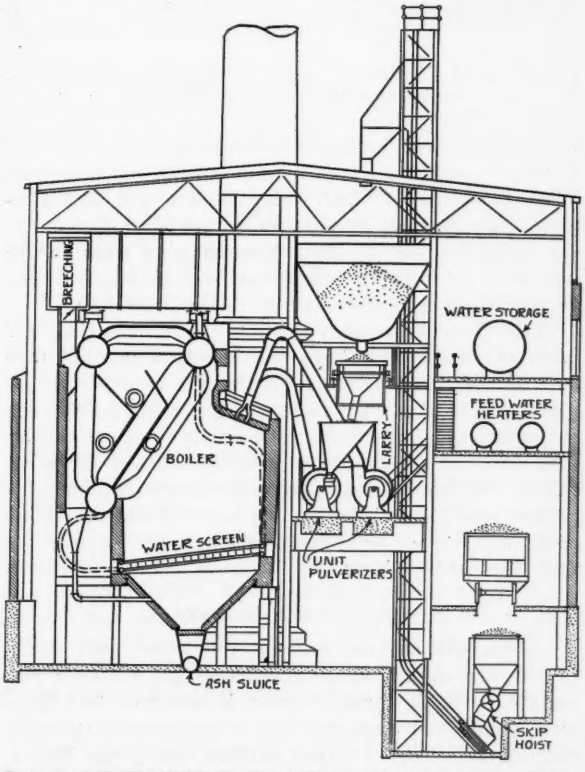


FIG. 5. SHOWING HOW SKIP HOIST LOADS INSIDE BUNKERS, FROM WHICH COAL IS TAKEN TO PULVERIZERS BY WEIGH LARRY

FIG. 6. VIEW OF THE WEIGH LARRY SHOWN IN FIG. 5

Transporting Pulverized Coal

SCREW CONVEYORS, COMPRESSED AIR AND BLOWING SYSTEMS, SCREW PUMPS ARE USED IN CONVEYING PULVERIZED COAL

PULVERIZED COAL cannot be handled by the usual coal handling equipment discussed in the previous articles. This is because, after coal has been pulverized, each particle is surrounded by an air film, friction between the particles is really that of air and not of coal and the final result is that the pulverized coal flows like a fluid and must be handled as such.

TYPES OF TRANSPORTING EQUIPMENT

Methods of transportation for pulverized coal may be roughly divided into five groups. Two or more of the groups may have to be used for a particular installation. These groups are: (1) the screw conveyor or the flight conveyor; (2) air pressure system, where compressed air is applied to blowing tanks to force the coal through pipes; (3) air mixture systems, in which the coal is mixed with about 50 per cent of the air needed for combustion; (4) pumping systems, using screw or rotary pumps, the pulverized coal being aerated; (5) transportation in tanks, barrels or other containers, a method seldom used in power plants and so far of little commercial importance in this country, although often used in Europe.

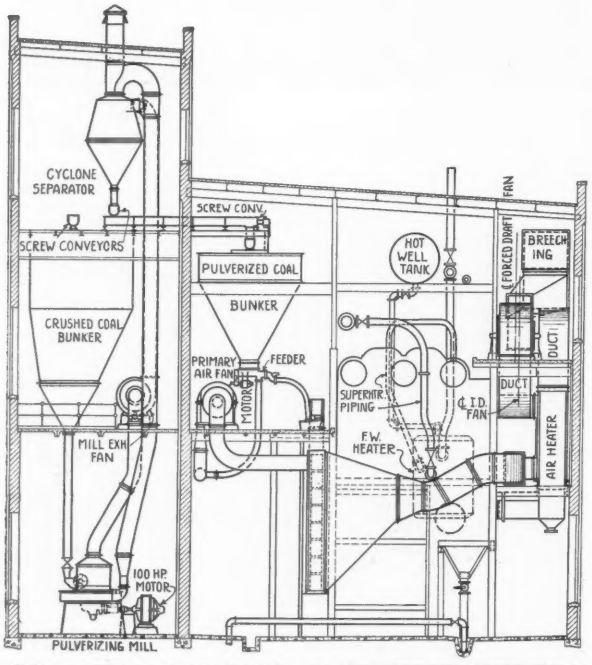


FIG. 1. IN A RECENT BOILER PLANT, SCREW CONVEYORS HANDLE ALL COAL IN PREPARATION PLANT

Screw conveyors, the original method of handling pulverized coal, are still widely used, especially for short distances. Change of direction or elevation with this conveyor can be made only with considerable complication. Such changes usually are taken care of by elevators. Many engineers recommend that single screw conveyors longer than 250 or 300 ft. be avoided in handling pulverized coal. Flight conveyors in several modified forms are used in much the same way as screw conveyors. Figure 1 shows a boiler house installed within the past year, using screw conveyors with a central preparation plant.

COMPRESSED AIR SYSTEM

Extensive use has been made of the compressed air system, Fig. 2. From a storage bin, the pulverized coal is delivered through flexible connections to blowing tank C, usually mounted on scales to weigh the coal delivered. When the tank is filled, valve B is closed and compressed air at from 10 to 60 lb. pressure is admitted to the tank, forcing the coal through pipe lines to the burners. Aeration or lubrication is sometimes effected by admitting compressed air to the delivery line.

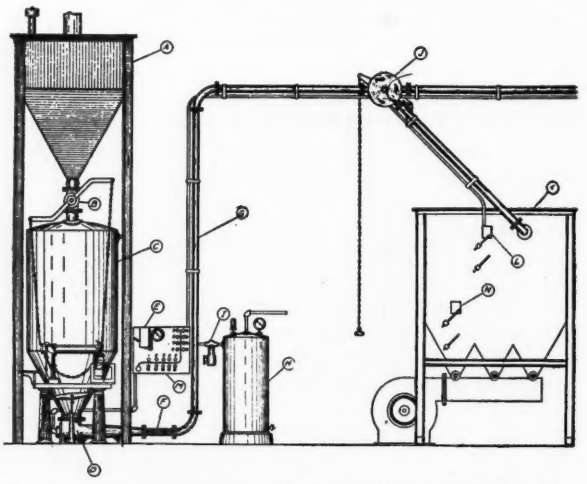


FIG. 2. AIR PRESSURE APPLIED IN TANK C FORCES PULVERIZED COAL THROUGH PIPING

Pipe lines of ordinary screwed pipe and fittings are used, reasonable elevations can be cared for and pipe may be run with the same convenience as water or gas pipe. Air used is only about one per cent of that used for combustion but suitable cyclones or vents are usually installed. In general, 700 to 1000 cu. ft. of air is required per ton of coal and total power requirements range from 2 to 4 hp-hr. per ton. Suitable remote controlled valves and signal systems are usually installed in the pipe lines.

AIR MIXTURE SYSTEMS

In the air mixture systems, pulverized coal is fed to a blower, usually by a screw feeder and together with the air drawn in by the blower, is delivered to a large main from which branches lead to the burners, the main running in a loop to return surplus coal to the blower. Air supplied with the coal is from 50 to 60 cu. ft. per ton of coal or about 50 per cent of the required com-

bustion air, at about 10 oz. pressure. Fine and uniform pulverization is necessary if the coal is to remain in perfect suspension.

Pumping Systems

Pumping systems for pulverized coal, Fig. 3, are perhaps the most widely used transporting method in power plants at present, especially with central preparation systems. Here pulverized coal is delivered from storage bins to weigh bins mounted on direct-reading scales. From these it discharges to a screw or rotary pump and as it leaves this pump it is aerated with compressed air at from 5 to 75 lb. per sq. in., depending on conditions. It then flows through delivery lines of black steel pipe to the burners.

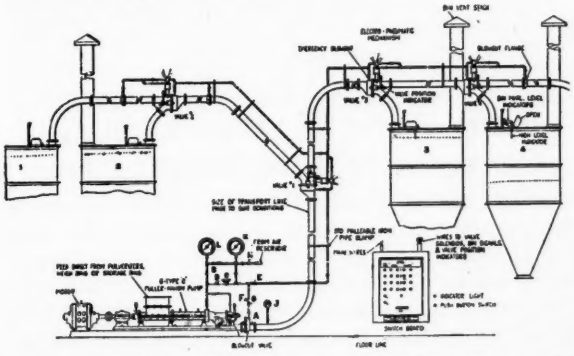


FIG. 3. TYPICAL INSTALLATION OF SCREW PUMP WITH ELECTRO-PNEUMATIC VALVE CONTROLS AND SIGNAL SYSTEM

In one system, valves on this pipe line and on storage bins are remotely controlled and operated by compressed air, while an elaborate signal system gives the operator full control at all times. Amount of air used is small. By this system, material has been successfully conveyed to distances up to one mile and single installations ranging up to 100 t. an hour are in operation with power requirements between ¾ and 3 hp. per ton per hour.

Another recently-developed coal transporter has two screws, one vertical and one horizontal. The vertical screw advances the coal downward through the hopper to the horizontal screw, which advances the material into the sphere of action of a rapidly moving stream of air under pressure. The coal that fills these screws offers full resistance to any back air pressure. The pulverized coal is advanced through the conveyor pipe to its discharge under air pressure.

Construction schedule is being maintained on the new 1700-kw. hydroelectric unit in the Big Forks plant of Mountain States Power Co., near Big Forks, Montana. The plant changes are expected to be completed and the unit in operation by December 1, according to H W. Fuller, vice president in charge of engineering and construction, Byllesby Engineering and Management Corp. The capacity of the plant will be increased from 2700 kw. to 4400 kw. by the installation of this unit. The plant is located on the Swan River.

Man's freedom to meddle casually in the processes of nature is the first pledge to his creativeness.—Baker Brownell.

Metering and Weighing Coal

Use and Advantages of Platform and Track Scales, Weigh Larries and Coal Meters

TO DETERMINE the performance of any boiler or battery of boilers, it is absolutely necessary to know how much coal is burned in their furnaces. In some plants, it is desired to know this only for the entire boiler house; in others, it is desired to know it for each boiler, so that it can be used, with other data, to give continuous records of performance which are, on the whole, considered more useful from the economic standpoint than infrequent special boiler tests. Consideration of operating conditions, costs and other factors determines the type and elaborateness of the coal-measuring equipment to be used in a given case.

Platform and Track Scales

The simplest method for weighing coal is, of course, the ordinary platform scale, on which wheelbarrows or other containers of coal can be weighed before being taken to the boilers. When coal is run into the boiler

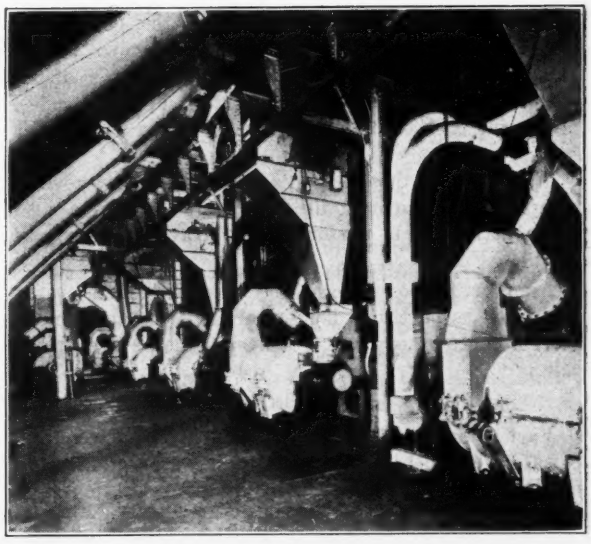


FIG. 1. EACH OF THE UNIT PULVERIZERS IN THIS BOILER HOUSE HAS ITS COAL WEIGHED BY INDIVIDUAL AUTOMATIC APRON FEED SCALE

house in narrow-gage industrial cars, as it is in some installations, a scale can be set in the track.

Track scales for weighing railroad cars are often provided in all types of plants. In some cases, this constitutes the only coal measurement taken of incoming coal, although it is sometimes checked by comparing it with the emptying and filling of coal bunkers or bins of known capacity. In many plants, other weighing devices supplement the measurements given by the track scales.

Fixed Automatic Scales and Weigh Larries

One form of coal-weighing device consists of a fixed automatic scale at each boiler, between the bunker and the stoker hopper or between bunker and pulverizing mills. Such scales usually consist of a weighing hopper suitably mounted on the scales with a power-driven

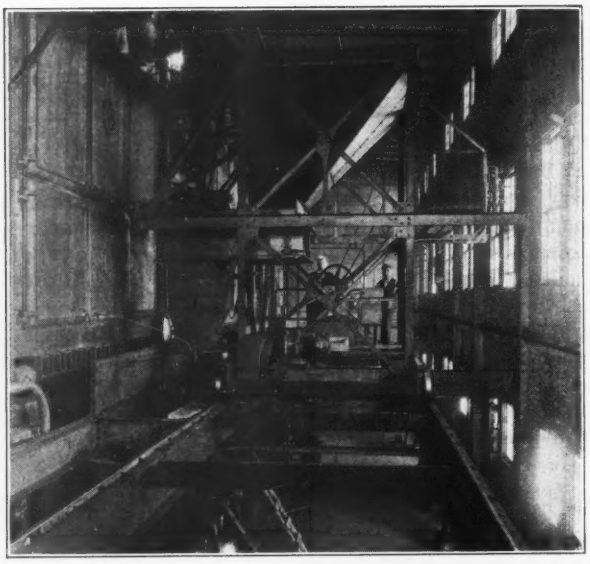


FIG. 2. AUTOMATIC RECORDING WEIGH LARRY SERVING A BATTERY OF STOKER-FIRED BOILERS

feeding device, automatic equipment for controlling charge and discharge of the weighing hopper and a means for registering and recording the readings of the scale. Figure 1 shows an installation of such scales, one serving each of the unit pulverizers in a large boiler house.

Where one of these scales is required to serve several stokers or pulverizing mills, as pointed out in a preceding article, it is mounted on a traveling larry, as shown in Fig. 2.

Another type of scale has been developed that is incorporated as part of a horizontal conveyor and weighs the coal continuously as the conveyor moves it over the scale.

Coal Meters

Various types of meters, as distinct from weighing scales, have also been developed. One type of meter is installed, as shown in Fig. 3, on the spouts leading from bunkers to stokers or pulverizers. It is operated by a vane, projecting in to the center of the spout; coal moving down turns the vane a definite amount for each foot of coal travel and this motion is transferred by flexible shaft to a counting device.

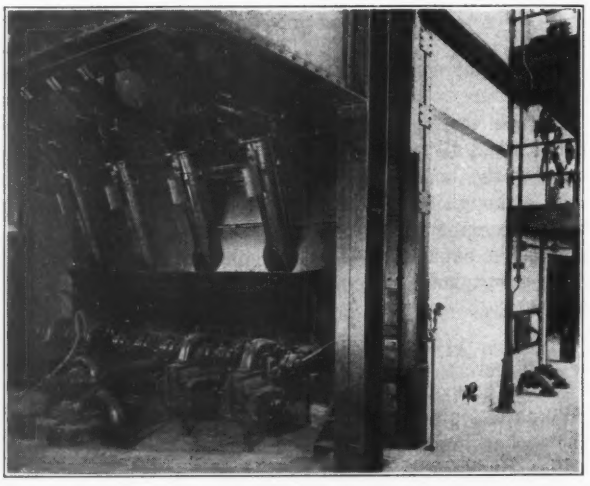


FIG. 3. COAL METERS ON STOKER SPOUTS

Another type of meter is attached directly to the stoker crank shaft to count its revolutions, while still another is actuated by oil pressure, the oil pipes leading to a gage calibrated in pounds of coal. With chain grate stokers, coal is often measured by calibrating the height of stoker gate and speed of grate surface.

For measuring pulverized coal—not raw coal—weigh bins are mounted on scales with flexible pipe connections as described previously. Speeds of coal feeders discharging to burners also give a measurement. These are sometimes screw feeders. There are also feeders in which the coal is pushed by a rotary element through apertures in a plate and these can be calibrated to give a measurement of pulverized coal used.

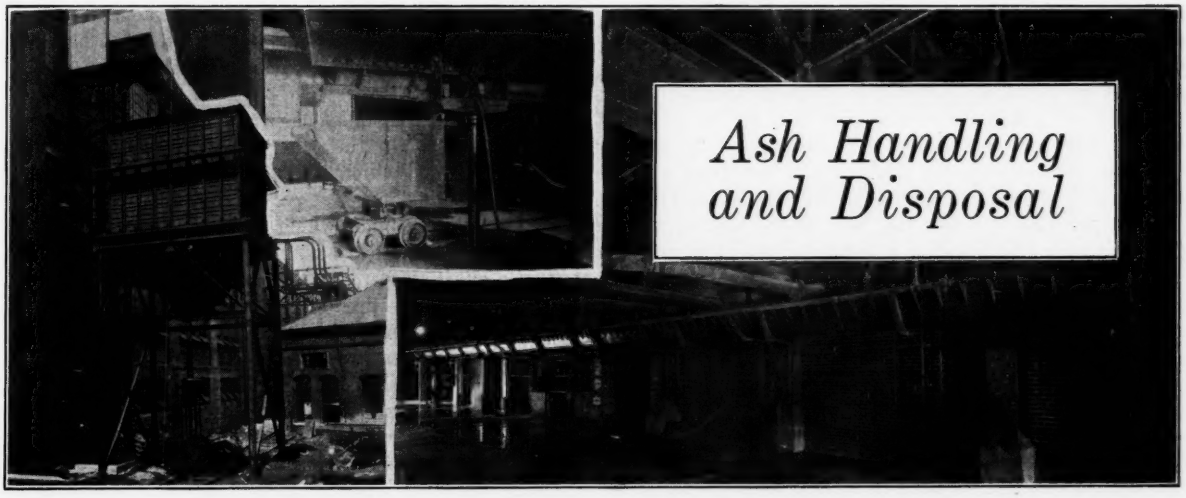
Power Factor of Street Lighting Corrected by New Transformer

By means of a unique combination of capacitors and transformer mechanism in the same tank, General Electric Co. has produced a constant current transformer having a unity power factor primary at full load, thus overcoming a major complaint of central stations against this type of transformer for street lighting service. The complaint was that when constant current transformers were operated at partial load, or even at full load, the power factor was low and, in case of a heavy industrial load having a naturally low power factor, the addition of a low power factor street lighting load penalized the central station severely since it was necessary to have a large kilovolt-ampere generating capacity although the kilowatt connected load was much smaller.

This new transformer, known as the type ROC, consists of a combination of capacitors and the standard RO transformer. The capacitors are connected in multiple across the primary. Because of the inherent characteristics of capacitors, it was found that they could not be installed in the same oil as the RO transformers, hence they are housed in a container welded, in the case of the standard 10-kw. size, to the front of the standard RO tank. In this way the best possible shape for pole mounting is preserved.

New Record Set for Peak Electric Load

According to a statement recently issued by officials of the Public Service Electric and Gas Co., all records for peak electric loads in the history of that organization were shattered on Thursday, November 8. Between three and five o'clock on the afternoon of that day, the peak load in the northern and central areas served by that organization reached 389,000 kw. The gradual but steady increase from 3:00 to 4:50 p. m. (when the peak was attained) amounted to 106,500 kw. This unprecedented demand for electric light was doubtless caused by the appearance of heavy storm clouds which served to increase the darkness of an originally dull, gray day. The former peak-load record of this company—372,500 kw.—was established on November 28, 1927.



Ash Disposal Systems and Requirements

Composition of Ash, Difficulties of Disposal and Essentials of a Good System. By W. K. Liggett*

COALS FROM different mines, when compared, show earthy matter or ash contained in them to vary within wide limits both as to its quantity and its chemical composition. This is to be expected when the origin of the ash is considered. It is derived from two independent sources. Part of it was contained in the fibers of the plants from which the coal was formed. Another and usually the larger portion came from the infiltration and mechanical admixture of earthy substances during the formation of the coal.

That portion coming directly from the plants is inherent in the coal. The plants took it up from the soil during their process of growth and held it intact until they became coal. This ash is, therefore, fairly uniform both as to its quantity and its composition. It is found in all coals and is so thoroughly mingled with them that it can not be separated by any purely mechanical means.

Ash which was added to the coal during its formation was the earthy matter which was washed and squeezed into the crevices between and around the fallen plants before they had become coal. This ash sometimes adheres to the coal but is seldom closely incorporated with it. Being heavier than the coal, it may often be separated from it by crushing and washing. Much of it is also thrown out at the picking table.

When the picking table and the washer have done their best and all the ash possible has been removed by mechanical means, a quantity of it still remains which is separated from the coal only during the process of combustion. This is the ash usually left in the furnace. It must be taken care of in order to enjoy the benefits of a good coal fire.

Crushing Coal

Crushing the coal may modify the difficulties of ash disposal but does not eliminate them. Primarily, coal is crushed for the influence on washing or burning. Crushing does not reduce the ash. In a more or less modified form, ash troubles obtain all along the line from selected lump to powdered fuel.

*Consulting Engineer, Jeffrey Mfg. Co.

Ash Disposal Difficult

Among many others, three characteristics of coal ash make its disposal particularly difficult. The dust arising from dry ashes is irritating and annoying when it is allowed to permeate the air or settle on surrounding surfaces. This dust nuisance calls loudly for abatement. One of the simplest of the common ways the fireman has for getting rid of it is to wet down the ashes before removing them from the pit. While this is satisfactory so far as the dust is concerned, it has several disadvantages. One of these is to lower the temperature of the ash pit to such an extent as to interfere with the efficiency of combustion; so the live furnace man is continually looking for better methods of handling the dust.

Clinker Will Form

Another characteristic of coal ash, making its disposal difficult, is its tendency to form clinker. When in a partially fused condition, coal ash becomes quite plastic and sticky. It will form into great beds of clinkers, if allowed to mingle in this plastic state.

Form, size and condition of these pieces of clinker can be largely modified by methods of stoking well understood and followed by good furnace men. Mechanical stokers are usually provided with automatic devices to prevent the formation of or break up this clinker but, when once a large piece has formed, heroic methods are about the only ones capable of dealing with it. The fire must be cleaned by hand.

The third characteristic of coal ash making its disposal difficult is its abrasive nature. The liberal amount of silica contained in all coal ashes insures a clean, sharp, cutting action whenever it comes into rubbing contact with other substances. Ash dust sifted into bearings will ruin them in a short time. Pumps han-

dling water mingled with ashes soon wear out. Small particles, even down to the colloidal form, will soon cut the blades and casings of fans. Pipes are worn out, especially at the elbows or turns. Troughs or any surfaces on which the ashes slide are soon disintegrated. In fact, any surface which comes into active rubbing contact with coal ash cinders disappears as if by magic.

Some materials resist this wear better than others but none of them have proved entirely satisfactory. It is good practice to select the best wear-resisting materials available (price being a factor in best); to protect all wearing parts from direct contact with the ashes; to make them more durable or of such form and material as to be easily and cheaply replaced; to avoid rubbing contact; to carry the ashes rather than scrape them.

Development of Ash Disposal Systems

When ashes are to be removed from a small stove, they are shaken down into the ash pan in which they are carried out and emptied in a convenient place. For larger stoves and greater quantities of ashes, buckets are substituted for the ash pan and a special receptacle provided for the ashman.

Still larger amounts require wheelbarrows in place of buckets. The ash bin becomes larger and is more conveniently arranged. Soon the ash bin must be elevated, so that the contents may be dumped into the wagon without shoveling. This requires a hoist or elevator to deliver ashes from wheelbarrows to ash bin. Then wheelbarrows are replaced by other forms of conveyors or hoists to deliver them to the bin.

Essential Elements

As the plant increases in size, many devices are added to save attendance or to make the system more cleanly or efficient. Conditions may arise which justify an entirely new system. Any case, however simple or complicated, involves three distinct operations:

A. Removing the ashes from the furnace and loading them into a conveying system.

B. A more or less complicated conveying system to deliver the ashes from the furnace to a storage.

C. Means for disposing of the stored ashes.

These operations are more or less independent of each other yet two or more of them may be combined into one. To form a true system, all of them must be thoroughly co-ordinated, the one following the other in natural sequence. Ashes may be loaded by shoveling and raking into wheelbarrows, pivoted buckets or other mechanical conveyors, into exhaust air openings, or into a stream of running water. They may also be allowed to fall directly into an ash car, a body of running water. or other device by which they are carried at once to the required destination.

The conveying system will also depend largely on local conditions: Whether the ashes are to be moved continuously or in batches; whether they are to be held in storage or disposed of at once; whether a large quantity of water may be available; whether the storage be elevated to be discharged into cars, depressed to be picked up by grab buckets, or omitted entirely, the ashes being spread out to fill some waste place.

Multiplicity of Systems

All these and many other factors will determine the choice. Many ash disposal systems have been proposed to accomplish these results and some of them have been developed to a high degree of perfection. We have the rough mechanical devices, with little attempt at protection against wear but with parts so cheap and easily assembled that they may be profitably scrapped after a period of use. On the other hand is the highly specialized system which has more conveniences, lasts longer and costs more.

There are systems which make a lot of dirt, and others practically dustless. Either of them may be worn out in a short time.

Some systems are cheap, others costly and the cheaper ones are not always the more economical.

Owing to the nature of coal ashes and the difficulties encountered in handling them, one is at a loss as to what system of ash disposal to select for any specific plant. Like the Irishman's choice of roads between two towns, "Whichever one you take, you'll wish you had gone by the other way."

While such a predicament as this often happens, a proper consideration of the case will usually disclose the best way before it is too late.

With the great variety of ash disposal systems which have been carried to a successful issue, and the many and varying conditions obtaining at every plant, it becomes a matter for considerable investigation and some experience before such a system can be well fitted to any particular case.

Conditions Obtaining Govern Choice

In the first place, it is well to fix in mind the conditions at the plant under consideration:

What quantity of ashes to be handled and is the work to go on continuously or are the ashes to be moved periodically, in batches?

What source of power is most convenient to use?

Is dust especially objectionable?

How are ashes to be loaded into the disposal system?

Can a car be placed under the ash pit to receive the ashes as they may be formed?

Will you be troubled with large clinkers?

What disposition is to be made of the ashes?

One can learn from the mistakes of others as well as from his own, and usually at a much lower cost. Visit several plants, especially those whose requirements are similar to your own. Observe the systems in use at these plants, especially as to the original plan, what modifications were made, why they were made. Were these changes necessary or desirable? How does the system work since they were installed?

Manufacturers of machinery relating to ash disposal systems can certainly supply some good literature relating to their devices. Get this literature and read it.

Since you must choose some system, make sure you choose the one best suited to your conditions.

Having decided upon the system you will use, do not be too confident of its immediate success. Do not spend all your funds for the first installation. Changes will be not only desirable but often quite necessary. Be in a position to make such alterations as your experience in the use of the plant may dictate and thus bring it up to its highest efficiency.

When you have obtained this efficiency and your plant has proved a success, tell your neighbors about it.

Methods and Means for Conveying Ashes

HANDLING ASHES FROM FURNACE ASH HOPPERS TO STORAGE BINS INVOLVES A CONSIDERATION OF ASH GATES, QUENCHING METHODS, CONVEYING EQUIPMENT, ASH CARS AND ELEVATING EQUIPMENT

ASHES AND clinkers that must be removed from the furnace in power plants amount in weight to between 10 and 20 per cent of the coal burned. The problem, then, of keeping the furnace clear of refuse and disposing of this waste material becomes of considerable importance not only in maintaining furnace efficiency but in holding down the expense chargeable to ash disposal.

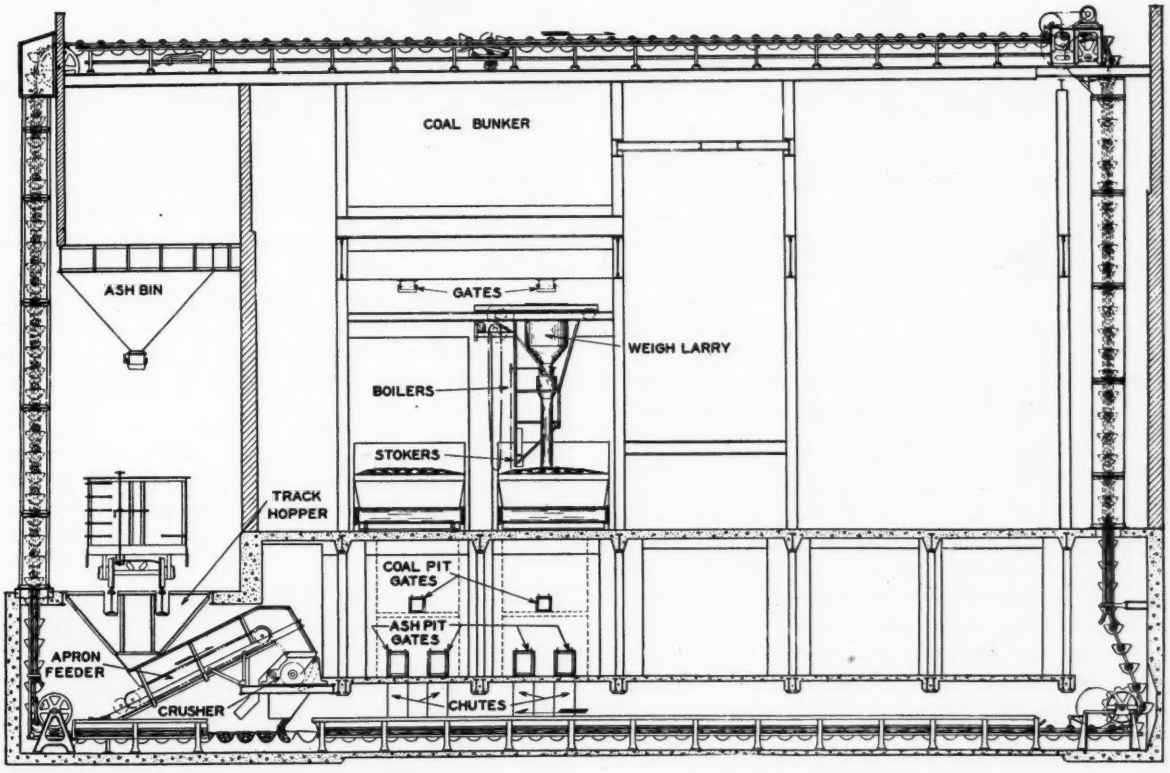


FIG. 1. COMPLETE COAL AND ASH HANDLING SYSTEM EMPLOYING BUCKET CONVEYOR

In many plants, the same equipment that is used for handling the coal can be used also for conveying the ash from the ash hoppers to the storage bin; other plants, however, find it less expensive to install an entirely separate ash handling system. Each plant should, therefore, be given separate consideration and the problem worked out for several different arrangements which have proved advantageous in other plants.

ASH PREPARED FOR HANDLING IN ASH HOPPER

Although the ash hopper is usually considered as part of the furnace, its design plays a considerable part in the selection of the ash handling equipment as it affects the condition of the refuse to be removed.

Ash hoppers serving stokers are usually designed to hold the accumulation of refuse produced during the full operation of the boiler for from 6 to 24 hr. Where conveying systems are installed, large capacity is not necessary as the ashes can be carried away as rapidly as they accumulate. Where the ash hoppers discharge into industrial or standard gage railway cars, however, large hoppers are essential as in operation the hoppers are dumped at regular intervals ranging from 6 to 24 hr.

Although ash hoppers are usually built up of reënforced concrete, in some cases lined with firebrick, hollow tile, so placed as to form air cooling ducts that furnish heated combustion air, are coming more and more into use and there is now on the market a manufactured hopper made of steel, cast iron and refractory tile. The cast-iron walls support the tile lining and protect the steel from the corrosive ash water, while the steel framework carries the total weight of the hopper and its contents. The sectional plate construction provides leeway for expansion and contraction due to temperature changes and the sections being man size are easily handled.

During recent years, it has become customary to equip underfeed and V-type stokers with clinker grinders. The principal object is to crush the clinker to such a size that it will pass through ash gates and can readily be handled by the entire ash-handling system. Another

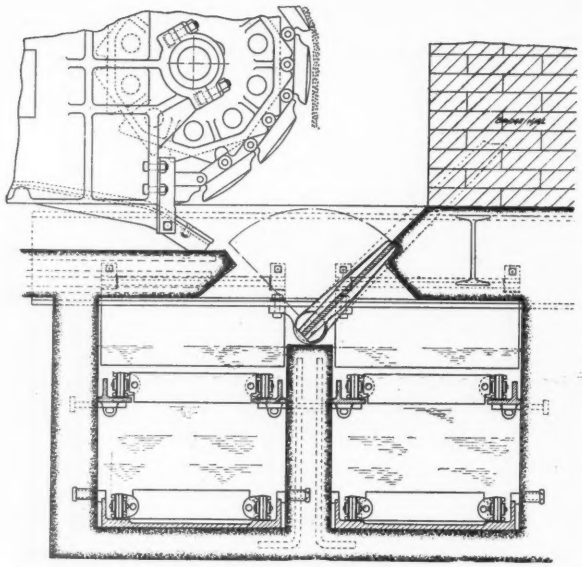


FIG. 2. SECTION THROUGH DOUBLE TROUGH CONVEYOR OF THE FLIGHT TYPE WHICH QUENCHES ASHES AS THEY FALL FROM THE STOKER

advantage is that they hold the refuse in the hopper until it has cooled to such an extent that it will do no damage to the conveying system and at the same time, by an accumulation of ash, preventing cold air from entering the furnace at the discharge end of the stoker.

Ash hoppers that are not provided with clinker grinders and must be dumped intermittently should be provided with a quenching device. This usually consists of a spray pipe which encircles the inside of the hopper near the top. Shortly before it is expected to dump the ashes, a spray of water is turned on and the contents of the hopper thoroughly wet, thus quenching any combustion that may be taking place in the refuse.

One type now available consists of any desired number of units properly spaced around the hopper to distribute a fine spray of water over a large area and thus provide ash quenching with the least amount of water. This arrangement prevents the combustion of unburned carbon in the hoppers and when used with a water-tight ash gate, air seals the furnace and eliminates flying dust during the discharge of ashes to cars.

These quenchers can be installed in any hopper wall and all piping is outside the hopper where it is always accessible and away from the intense heat. Where necessary, however, quenchers can be supplied for support from the piping.

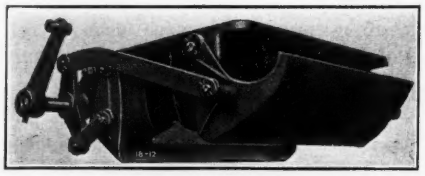


FIG. 3. TIGHT-FITTING, LOW BODY DUPLEX CUTOFF ASH GATE

Another means of quenching sometimes used with flight conveyors is to provide a water-tight trough for the conveyor. This forms a seal at the bottom of the ash hopper and the water quenches what burning particles drop to the conveyor.

Ash hoppers for pulverized fuel furnaces are rather special in their construction. In modern practice, the ash is taken from the ash hopper in granular form or drawn off as molten slag direct from the furnace. Where ash hoppers are provided, they are in the coolest part of the setting, either screened in some way from the combustion space or provided with air or water-cooled walls. Ash from these furnaces can be discharged through gates to the conveying system as from stoker hoppers. With slag tapping furnaces, however, the universal

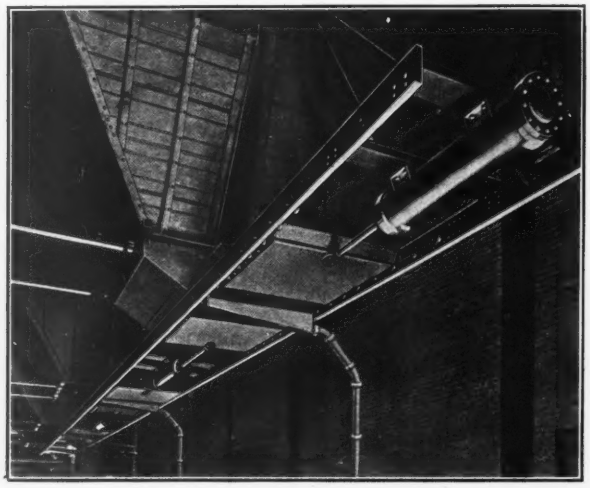


FIG. 4. PNEUMATIC PRESSURE IS USED TO OPERATE THESE 5 FT. BY 5 FT. WATER COLLECTING ASH GATES

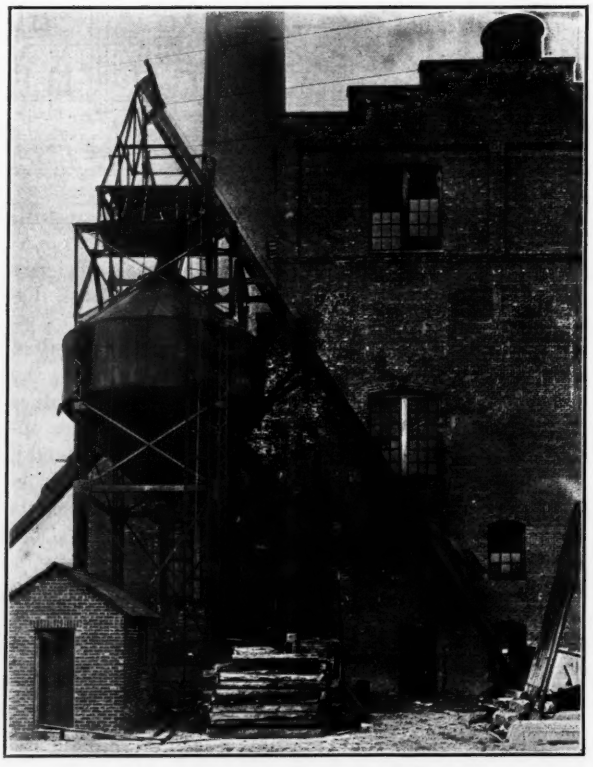


FIG. 5. ASH HANDLING SKIP HOIST

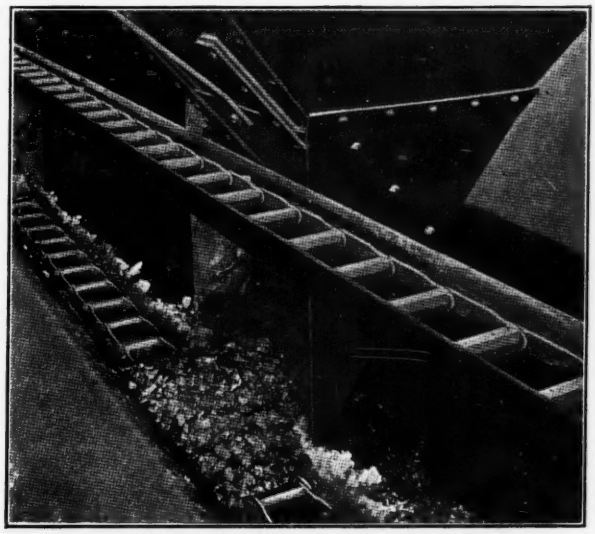


FIG. 6. CHAIN CONVEYORS RECEIVING ASH FROM FURNACE HOPPER

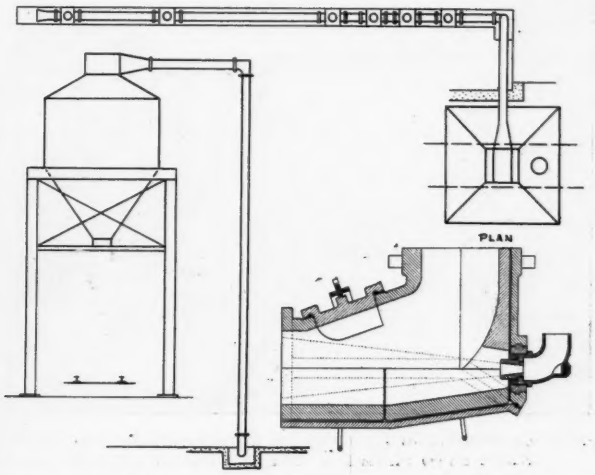


FIG. 7. GENERAL ARRANGEMENT OF A STEAM JET ASH CONVEYOR AND DETAIL OF A STEAM JET

method is to draw molten slag off into a stream of water that cools and breaks up the slag into small particles which can be handled by sluicing.

Ash Hopper Gates

Gates used to discharge the ashes from the furnace ash hopper are subject to extremely hard usage and although coal gates are used extensively they are not found satisfactory in all cases. For this reason, special gates have been developed. Gates for this purpose are subject to rapid changes in temperature and must work freely at both extremes. They are also subject to the corrosive action of quenching water and are consequently usually made of cast iron. If quenching is done in the hopper, as is preferred by many engineers, a wet basement will result if the gate is not water-tight. Then, too, head room is at a premium and the less the gates require the less expensive they are to install. One of the simplest yet serviceable gates used for this purpose is shown in Fig. 3. It is of the duplex cutoff valve type, tight fitting with low body and outside flanges, heavily built to withstand hard usage, corrosive action of water and high temperature.

With increasing sizes of boilers has come need for ash gates of large capacity and we find in many plants ash gates that are operated either by hydraulic or pneumatic pressure as are those shown in Fig. 4. These gates are of the sliding type suitable for water tight hoppers, the quenching water being collected and drawn off by the piping shown. They are assembled and tested in the factory and shipped ready for operation. The same type of gate may be designed for operation with rack and pinion.

Conveying Ash in Cars

One of the oldest methods of handling ashes that is still used to advantage in many modern power plants is by means of industrial cars run on narrow gage track. These cars are low so that they run directly under the ash hopper and, if properly selected as to size, will hold the entire contents of the ash hopper in one load. If the ash pile is close to the plant, the cars can be run out and dumped without further handling. In some cases

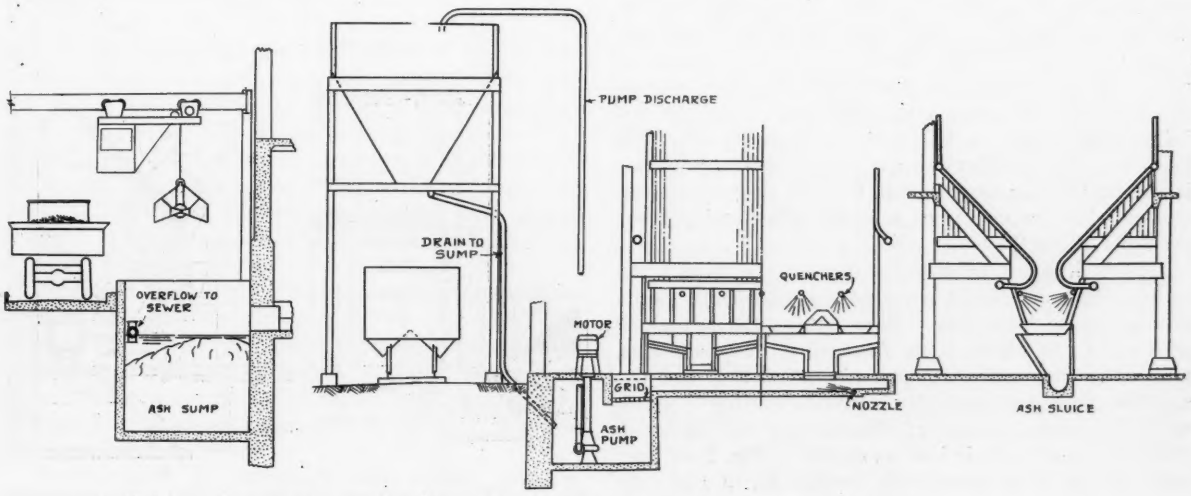


FIG. 8. TWO METHODS OF HANDLING ASH BY THE SLUICING

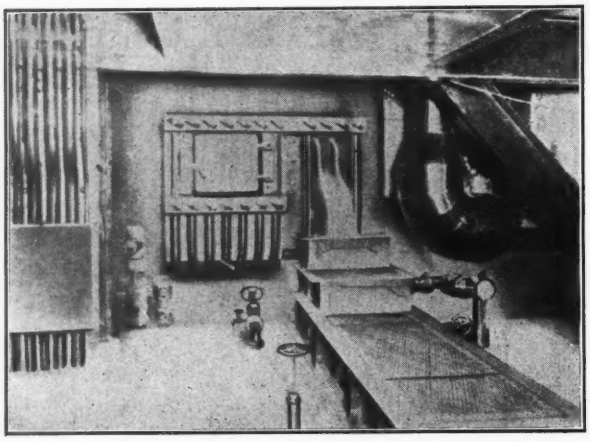


FIG. 9. REMOVING SLAG FROM PULVERIZED COAL FURNACE INTO SLUICING ASH HANDLING SYSTEM

the levels are such that cars can be dumped from an elevated track.

When disposal must be made by means of trucks or railroad cars, an arrangement commonly employed is to dump the ashes from the industrial cars to a skip hoist which delivers to an elevated ash bin. Some office buildings run the loaded cars on elevators and dump direct to hoppers which discharge in turn to trucks for disposal. Another arrangement sometimes employed is to locate the ash bin in the basement and use a sidewalk bucket elevator to deliver to the truck.

In large plants where ashes amount to several car loads a day, provisions are sometimes made to run trucks or gondola railroad cars directly under the ash hoppers thus saving entirely the trouble of handling the ashes at the plant.

One of the principal objections to the car systems for conveying the ash is the fact that they require considerably more head room than several other systems now available, such as bucket, flight, pneumatic and sluice conveying systems.

Systems for Continuous Conveying

Where bucket conveyors are installed, they are usually required to handle both the coal and ash, as was illustrated in Fig. 1. This is accomplished by placing the upper run over the coal bunkers and ash storage bin and the lower run conveniently located to receive the discharge from the ashpits and the coal unloading hopper or preparation equipment. The buckets, being made of metal, will handle the ashes hot from hoppers without difficulty; wetting the ashes, however, is the practice in some plants to keep down the dust, quench what fire may remain in the refuse and prevent gas from filling the boiler room.

Where it is not necessary to elevate the ashes vertically, a chain or a flight conveyor is applicable in plants of medium to large size. These scrape the ash along in troughs, the flights being fastened to endless chains, and while they will carry up an incline they are not suitable for lifting vertically. When elevating is necessary, V-buckets instead of flights may be employed. They may receive their load as shown in Fig. 6, or they may be run in a water-tight trough which not only quenches the ash but seals the hopper, see Fig. 2.

During recent years, pneumatic systems, because of their simplicity, flexibility and cleanliness, have been growing in popularity for conveying ashes from the ashpit hopper to the storage bin located at the most convenient place about the building or grounds for discharging to cars or trucks. Where the vacuum is created by an air pump or a steam ejector attached to the exhaust of a cyclone separator, the ashes are always dry and no difficulty will be experienced with ashes freezing in the storage bin. With some arrangements, however, the steam ejector is placed in the conveying pipe line and the steam condensate wets the ash.

Sluicing systems have come into favor during recent years, particularly in powdered coal installations. As usually installed, the ash is discharged from the hopper into a stream of water running at high velocity. The discharge is usually to a settling tank from which grab buckets, operated from some form of crane, deliver the ash to cars or trucks for disposal. The ashes may, however, be delivered to an overhead ash tank by means of a pump placed in a receiving sump. When the ashes are used for filling low ground around the plant, the sluicing system is all that is needed for conveying the ash. The same is true where the plant is located on the bank of a swift flowing river.

Ash Disposal Methods

Types and Arrangements of Apparatus Are Discussed and Advantages Indicated

ASH DISPOSAL SYSTEMS depend, for their adoption, upon the nature of the ash and the quantity handled. For small plants, ash dump cars, usually running on industrial tracks in front of the boiler ash pits, are frequently used. Such cars are pushed to the receiving hopper of some elevating device and dumped. The ash is then elevated to the ash storage bin from which it is passed by gravity through a chute to the trucks or cars and hauled away, as shown at A in Fig. 1.

In some cases, the chute leads to the firing floor of the boiler room and the ash is discharged into industrial cars as shown at B. Another alternative is to dump

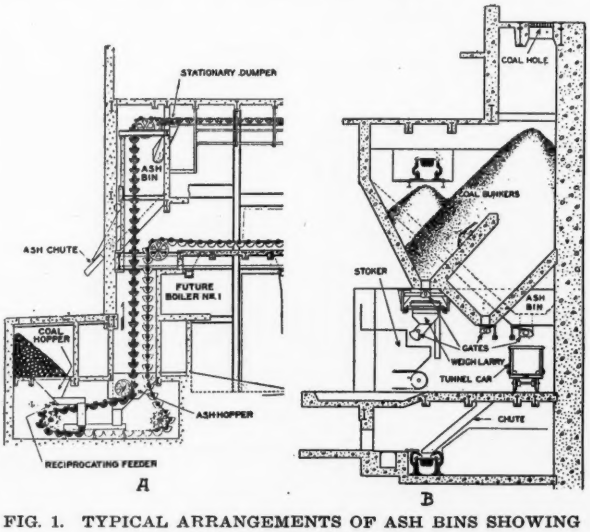


FIG. 1. TYPICAL ARRANGEMENTS OF ASH BINS SHOWING HANDLING METHODS

the ash into a pit from which it is removed by means of a grab bucket as indicated in Fig. 2.

Dust Elimination

Discharge out of doors has the advantage of permitting greater cleanliness in the boiler room. Some installations provide for eliminating the dust. After

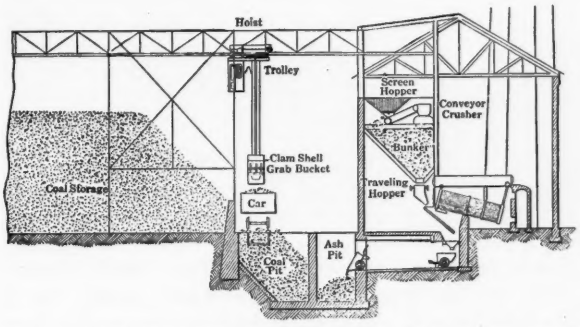


FIG. 2. TELPHERAGE SYSTEM USED FOR BOTH COAL AND ASH HANDLING

the ash has been deposited, the foul air is carried to an exhauster but a filter is interposed in order to extract the dust, which is deposited in a sludge tank, whence it is periodically removed. If not removed, the fine sharp particles held in suspension would subject the exhauster to excessive wear.

Telpherage System

Telpher transportation consists of a hoist which not only lifts the material but transports it overhead on a

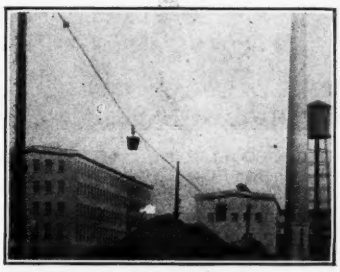


FIG. 3. CABLE HUNG TELPHERAGE CONVEYOR FOR SMALL PLANT

rail, usually a monorail, or on a cable. A typical telpherage system which is used for handling both ash and coal is shown in Fig. 2. The cable type, which is a simpler and much less expensive telpherage system, is shown in Fig. 3. The length of haul is limited only by the length of the runways. The minimum radius of track is 15 ft. when telphers are provided with swivel trucks. The load on standard machines is limited to about six tons.

Turntables, operated from the cab, are provided when required in rail installations. Telphers are usually operated electrically, the operator's cage being part of the trolley carrier and all control is effected from that point. Hoisting speeds vary from 25 to 200 ft. per min. and travel speeds from 250 to 1000 ft. per min., depending upon local conditions.

Buckets used in connection with telpher systems are arranged to open automatically when they come in contact with material in the place of discharge, the contact releasing a latch at the bottom of the bucket and opening two doors for the discharge of the load. In some installations, the hoist and operator do not travel with the load. Such telphers are less expensive but they cannot be controlled so well in large areas.

Bins Located for Convenience of Discharge

Ash storage is accomplished in overhead bins or underfloor pits, the former being constructed of steel or concrete as a part of the building or hung from supports, as shown in Fig. 1. When made of steel, they have bottoms shaped for strength in a catenary curve. One storage hopper is constructed of cast iron plates in order better to resist abrasion and corrosion. These hoppers are elevated on structural steel supports and placed at any convenient location near the boiler house. Another type has a lining of concrete.

Several types of cars are shown in Fig. 4. Other types are the hopper-bottom type and the gable bottom type which has doors on both sides swung at the top and arranged to be opened simultaneously. Cars are supplied with either roller or plain bearings. The cars

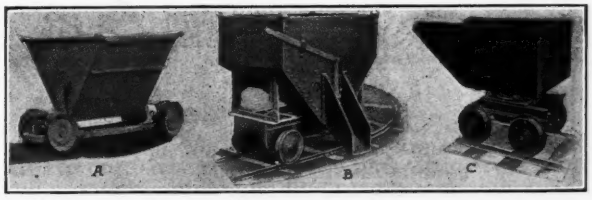


FIG. 4. TYPES OF INDUSTRIAL CARS USED FOR ASH

selected depend upon the location of ash dump. If cars are used for other service such as coal handling, they may also be used for the ash as the latter service is only occasional. Dump cars are usually designed to carry 12 to 40 cu. ft. of material but are manufactured up to 80 cu. ft. capacity. The minimum allowable radius of track is 12 ft.

Combustible Reclamation

Separation, Dustless Collection and Briqueting of Waste Fuel

COMBUSTIBLE MATTER contained in ash discharged from boilers ranges from 10 to 45 per cent where modern stokers are used; the average refuse pile contains about 30 per cent of combustible matter. The combustible found in ash from pulverized coal fired boilers is much less than that found in any other type of coal-fired boilers. Ash deposits taken from various parts of gas passages of the pulverized coal-fired boilers at one large plant have given the following per cent of combustible content:

Furnace bottom	0.10 per cent
First pass	2.24 per cent
Second pass	2.11 per cent
Economizer hopper	3.06 per cent
Fourth pass over wind drum	2.26 per cent
Total	9.77 per cent

Recovery Types

There are two types of machines for recovering coke from boiler house refuse, namely, dry and wet separators. The dry separators operate on the principle that most coal contains some iron which, during combustion, is converted into an iron oxide of sufficiently high magnetic susceptibility to separate coke from ashes. Wet separators rely for their operation on the difference in specific gravities of coke and clinker.

Removal of combustible, in one type of machine, is effected by two rotating sieve drums working in separate compartments and an inclined separating trough. Ashes are fed, as shown in Fig. 1, to the sieve drum which first screens out the fine dust; the remaining material goes over a coarse grid which rejects the large clinker and delivers the fuel-bearing material to the inclined separating chamber. This chamber is half filled with a solution of water and loam or any other soil

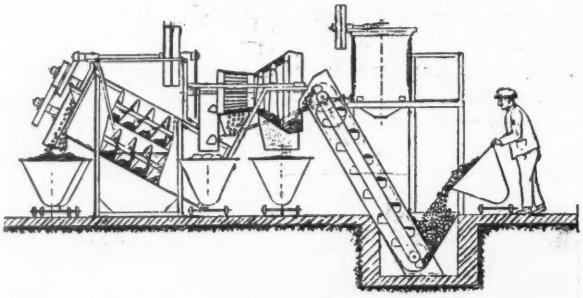


FIG. 1. WASHING AND SCREENING OF ASH SEPARATES COMBUSTIBLE MATERIAL FROM LOAMY MATERIAL AND CLINKER

that will raise the specific gravity of the liquid to about 1.25. Into the separating chamber dip the ends of two screw conveyors which are placed on an incline. The lower conveyor removes the material which has a higher specific gravity than the liquid and is worthless as fuel; the upper conveyor skims the material from the surface of the separating liquid and as this contains all the combustible material that is lighter in specific gravity than the liquid, it is returned to the coal bin for re-use.

Separation Accomplished by Flotation

Operation does not depend in any way upon the bearing capacity of a current of flowing water or upon the size and shape of the pieces of ash. The coke floats and the clinker sinks because of their difference of specific gravity and the separating fluid is the agent which delivers the coke to the proper chute and sends the clinker to other outlets.

In tests run with ash from a power plant, containing 30 per cent combustible, the reclaimed portion of the refuse amounted to 35 per cent of that fed to the machine, this ratio, however, may be varied somewhat by changing the specific gravity of the liquid. On an average, the heat value of the reclaimed fuel runs about 11,000 B.t.u. per lb. but this also may be varied by changing the specific gravity of the separating material.

Approximate analysis of this fuel shows it to contain from 75 to 80 per cent of carbon, 3 to 5 per cent volatile and the remainder, ash. Tests on chain grate stokers, in which normal boiler room efficiency was maintained, indicate that no difficulty should be had in burning this reclaimed fuel mixed with high volatile coal in percentages ranging from 25 to 60 of the total fed to the furnace.

Under present conditions, it is estimated that the cost of operating the apparatus, including repairs, interest on investment, depreciation, attendance and power cost, would be between $0.60 and $1.25 per t. of reclaimed fuel. Plants of 2000 hp. and up or those producing 3000 or more tons of ash a year, can, it is thought, use this apparatus for reclaiming fuel with economy. Capacities ranging from 1½ to 12 cu. yd. per hr. require from 1 to 4 hp. respectively for operation. Water consumption is from 15 to 40 gal. per hr.

Briqueting Methods

Reclaimed combustible may be briqueted by crushing and mixing it with by-product pitch and then forming it into small uniformly shaped pieces under a pressure of from 2000 to 4000 lb. per sq. in. Such briquets burn well but they give off objectionable smoke due to the pitch binder. Another method employs an extrusion press to form the briquets. At one plant the briquets are reheated to render them dense and smokeless.

Dustless Collection of Siftings

Considerable amounts of coal siftings and dust collect on the boiler room floors, piping and structure. This

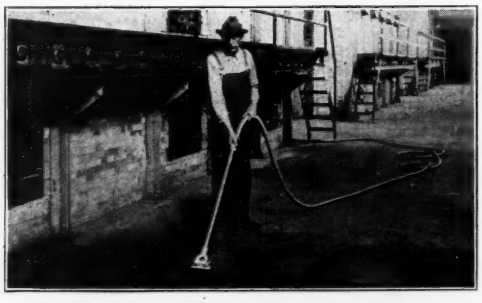
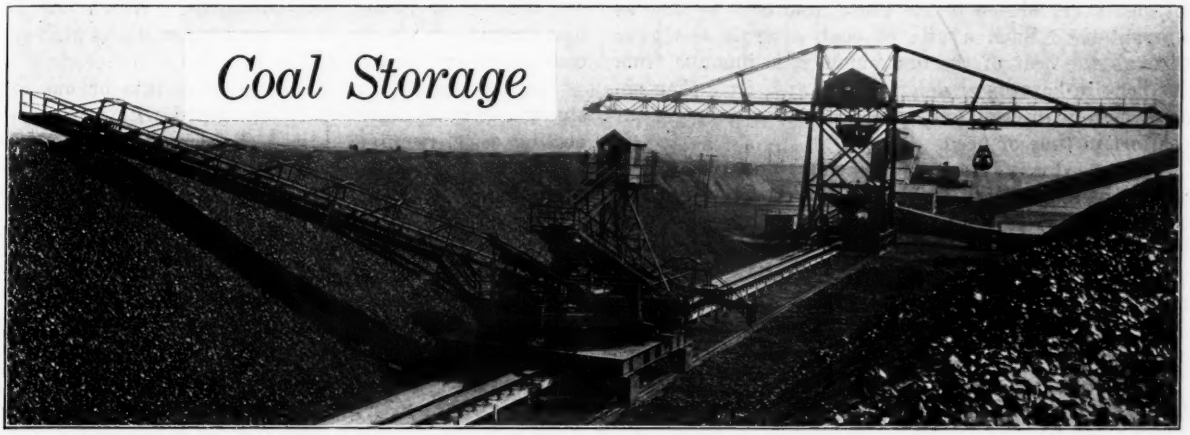


FIG. 2. DUSTLESS COLLECTION OF SIFTINGS NOT ONLY RECLAIMS FUEL BUT IMPROVE WORKING CONDITIONS, PROTECT PLANT AND EQUIPMENT AND MINIMIZE DUST EXPLOSION HAZARD

material is now being reclaimed by pneumatic means, as shown in Fig. 2 and lifted to an overhead collector from which it is delivered into the stoker hoppers. A vacuum of 5 to 9 in. of mercury is maintained in the pipe line leading to various parts of the plant, by means of a motor-driven, centrifugal vacuum producer.

Production of electric power by public utility power plants in the United States, according to a report of the Geological Survey, Department of the Interior, reached a total for August, 1928, of 7,484,942,000 kw-hr. Of this amount 4,442,873,000 kw-hr. were produced by fuels and the remainder, 3,042,069,000 kw-hr., by water power. The total produced is an increase of 12 per cent over that of August, 1927.

City Ice & Fuel Co., Cleveland, Ohio, has authorized an expansion and improvement program in its ice making, cold storage and refrigerating plants in different parts of the country, involving an expenditure of over $1,500,000. It is expected that the program will be concluded during the coming year.



Storage of Coal Is Good Insurance

Overhead Carrying Charges Should Be Considered Continuity of Service Expense Rather Than Fuel Cost. By W. L. Abbott*

SOME NECESSITIES such as air are supplied by nature in great abundance and far in excess of our immediate needs. Other necessities as food are, for the most of us, in storage in the icebox, at the corner grocery, in the warehouse and in the grain elevator. Other necessities, as city water at the tap and electric energy at the socket, are produced and delivered only as and when wanted or wasted.

Some people eat whenever and only when they get something to eat but, as a rule, mankind and various other creatures store up food against the day of non-production and want because they have learned that, in such a day, it is difficult to borrow, as the gay but improvident grasshopper learned in the chill of an early fall when she solicited alms at the door of the ant's storehouse.

Heat and Power Supply Are Vital

Ranging all the way from mean to extremes in the above illustration is our practice in storing up coal, although our commercial fabric is so complex and so interwoven that a serious disturbance of one function affects all, and in this system, no function is more basic and vital than that of the supply of heat and power. When they stop, everything else stops until that supply is again started.

True, we can scarcely conceive of such an interruption to the production or transportation of coal, that all our current and accumulated supplies would be exhausted for, with coal near at hand, although underground in the mine, before the fires of industry and in homes would be permitted to die out, we would dig out of snow blockades or we would compromise with or surrender to any demands. to avert the great disaster of fuel shortage.

Storage Experiences Sometimes Discouraging

But the menace of coal shortage due to traffic blockade and to strikes, with all its attendant discomforts and panicky prices, though remote is real and against it the coal user has, in the past, protected himself. He would protect himself much more than he ordinarily does, were it not for his recollection of rumors of shortage that never developed and against which he provided a pile of coal, which later went up in flame and smoke from spontaneous combustion, while his neighbor bought coal on the market at usual prices.

Also, coal which has lain in an out-of-door pile for a few weeks has undergone a chemical and a physical change, which make it less free-burning, although its heat value is not noticeably impaired. But that lowered free-burning quality profoundly affects the fireman and gives him a ready alibi for low steam pressure and the owner, who must usually take the fireman's word regarding the quality of the coal he burns, is compelled to assume when storing coal that, if it does not all go up in smoke from the storage pile, as it is liable to do, there will be on his hands an inferior lot of fuel that, in the end, will probably cost more with the handling, insurance and interests costs than day-to-day supply would have cost him even at panic prices.

Such sad experiences have inclined the user to store coal only to guard against the most imminent danger and to burn up that stored as soon as the danger is past.

Others, he reasons, will be storing coal and that will take those users out of the market, which of itself will tend to keep the price down, so he decides to take his chances without storage.

Large Users Maintain Adequate Stores

Such experience and reasoning apply, in most part, only to the coal user of moderate demand. The larger user, especially the utility, would no more think of being without a large stock of coal than he would think of being without the essential spare parts to his equipment. True, utilities have had experiences with coal fires but they now know how to store coal so that it will be practically free from all danger of spontaneous combustion, just as they know how to store it so that it will almost as surely take fire.

*Chief Operating Engineer, Commonwealth Edison Co.

Large users keep large stocks on hand indefinitely as an insurance, adding to the stock from time to time as warrantable. Such a pile of coal, after it has gone through the heat of the first summer, is immune from further fire hazards or deterioration and, from then on, costs merely interest and taxes. It is an ever-present comfort in time of need.

That need may be caused by strikes, blockades, a temporary increase in coal prices when the user would like to withdraw from the market for a time, or there may be a temporarily overstocked market of which the user would like to take greater advantage than his day-to-day need would permit. The permanent storage, lasting year after year, serves as protection against an infrequent but serious emergency; the temporary storage from month to month is used to avoid demurrage or take advantage of the low prices of a temporarily flooded market.

Continuity of operation is so vital to large coal consuming industries, and the cost of securing that continuity, so far as coal storage is concerned, is so moderate compared with the cost of insurance on smaller and less important risks, that industry cannot afford to be without that protection even though it is obliged to carry the insurance itself. Insurance companies do not as yet know much about the science of coal storage but they do know a lot about the difficulty of finding a market for a pile of burning coal, which an owner with proper equipment could readily reclaim and send to the boiler room.

Convenient Storage Is Essential

Essentials for a storage yard are accessibility from lines of transportation and convenience to the place where fuel is to be used. The term "convenience" may have many shades of meaning. The people of Italy, for example, would consider it convenient, if they had any coal seams at all in any part of their country or of their possessions. With us coal is not convenient until it is mined and delivered; even then, it is not perfectly convenient until it is in the bunkers. But, for purposes of storage, coal is conveniently near, if it is readily available when wanted.

Before it is mined, coal can be bought for ten cents a ton and such storage would be quite economical. But we can conceive of many emergencies where such storage would not be considered available. Coal could be mined and placed in a pile near the pit mouth without transportation charges but that too, for many reasons, might be impossible to deliver during coal shortage. The next step is to store the coal at or near the place where it is to be used, charged with full mining and freight costs and that sort of storage is the cheapest that can be considered.

If it is inside the fence and on the premises where it is to be used, the protection may be called perfect but, as storage space so conveniently located is seldom available, the greater part of the reserve may be kept a few miles distant, from which point the railroads will load it and bring it in without additional hauling charge.

Quick Handling Must Be Possible

To handle coal in quantity, a storage yard should be equipped with mechanical means for cheap and, above all, quick handling. For those purposes there is a choice of locomotive cranes, gantry cranes, car dumpers, drag scrapers and belt conveyors. Which one is best depends on the size of the yard, amount and kind of coal stored and length of time it is to lie in storage.

Actual cost of handling coal either into or out of storage, is quite insignificant compared with other operating costs, running as it does from five to twenty-five cents a ton. The greatest part of the cost of permanent storage of coal is the overhead charges for maintaining the yard and equipment and the carrying charges on the cost of the coal stored. These, taken at ten per cent a year, would, in a few years, double the coal cost unless that expense was charged off yearly to insurance, just as you would charge off the checking fee on your hat at the hotel restaurant to the cost of the meal and not allow those fees to increase gradually the price of a hat.

Storage Protects the Community

In a community a large storage is protection for all its coal users, whether the owner so intends or not. In the first place, it relieves a stringency by taking that buyer out of the market; and second, the owner of that store of fuel could hardly resist appeals to part with some of it to keep water works, schools and hospitals going. Neither would he hoard his coal while families shivered in their homes.

For a community, the protection benefits of a large accumulated storage are so great that it has often been suggested to make maintenance of such a yard a municipal function. The experiment has been tried in some places but with the usual result of a left-over, high-cost stock of degraded coal to be sold at a loss, bringing chagrin and dishonor to those who proposed the benevolent experiment.

Rather than having coal storage made a function of a municipality, it should be the duty of the coal trade itself to protect its customers and their coal supply. But to get coal operators and coal dealers to unite to make that great investment and to keep them united to share a probable loss, would require the diplomacy and tact of a—well of a Herbert Hoover.

Department of Commerce announces that, according to returns received at the quinquennial census of electrical industries taken in 1928, the total output of electric current in the State of Kansas in 1927, as reported by electric light and power plants, was 743,633,159 kw-hr., an increase of 57.2 per cent as compared with 473,070,278 kw-hr. in 1922. During the same period, the generator capacity increased at the rate of 59.9 per cent, from 204,131 kw. to 326,305 kw. Marked increases appear also in the horsepower of steam turbines and internal-combustion engines in use as prime movers, together with considerable but less pronounced decreases for reciprocating steam engines and water turbines. The 240 electric light and power establishments reported from Kansas for 1927 comprised 30 commercial and 210 municipal establishments. (The word "establishment" refers to ownership or control; consequently, in many cases, a commercial establishment represents two or more generating stations or distributing systems.) The corresponding figures for 1922 were as follows: Total, 290; commercial, 75; municipal, 215.

Protection and Cheap Coal Function of Storage

CONSIDERING THE COUNTRY AS A WHOLE SEVEN PER CENT EMERGENCY STORAGE AND NINE PER CENT SEASONAL STORAGE WILL TEND TO IMPROVE THE BUSINESS STRUCTURE AND INSURE AGAINST SHORTAGE DUE TO STRIKES AND TRANSPORTATION TIE UPS AT SMALL COST

STORAGE OF COAL as practiced by industrial and central station power plants is primarily a matter of protection against fuel failure which may be caused by strikes, uncertain railroad deliveries or coal shortages. As such, the economies of this emergency storage are not overly emphasized. The issue is dominated by factors of such moment that the price variations of coal

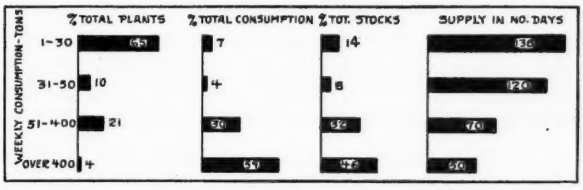


FIG. 1. IN TERMS OF DAYS' SUPPLIES, SMALL PLANTS CARRY MORE STORAGE THAN THE LARGE ONES

one way or the other due to storage are of small importance.

In most industrial establishments, the fuel cost will be a small fraction of the total production cost so that even doubling the fuel cost for a short period would be relatively unimportant when compared with the loss entailed by a complete shut-down due to failure of the fuel and power supply. In the public utility field, the matter is of even more importance as a power failure means cessation of activities in not one but hundreds of plants.

In addition to emergency storage, there is the so-called seasonal storage which is dominated solely by

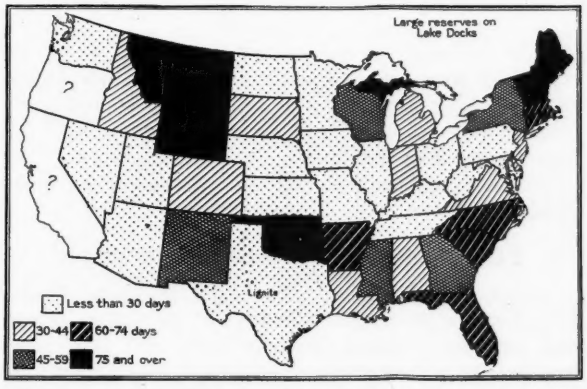


FIG. 2. DAYS' SUPPLY OF BITUMINOUS COAL ON HAND AT GENERAL INDUSTRIAL PLANTS OCTOBER 1, 1928

economics. Seasonal storage is for the purpose of taking advantage of low coal prices or low freight rates at certain seasons of the year.

Just how much storage is necessary in a specific case depends upon a number of individual factors such as nearness to the coal fields, transportation facilities, importance of continuous operation, stability of the coal and labor market and the availability of other fuel. As a general rule, seasonal storage of from 8 to 10 per cent of the annual consumption and a reserve or emergency storage of about 7 per cent will answer the needs of most plants.

As might be expected, the large consumer carries a somewhat smaller storage than does the small consumer. For, although the storage of coal presents no serious trouble from breakage, spontaneous combustion or deterioration, its storage involves insurance, taxes, storage facilities and handling equipment which may well make large storage impractical.

Furthermore, large users receiving frequent shipments are in a better position to obtain sufficient supplies to augment this storage in case of trouble. The typical industrial user is one who uses one carload or

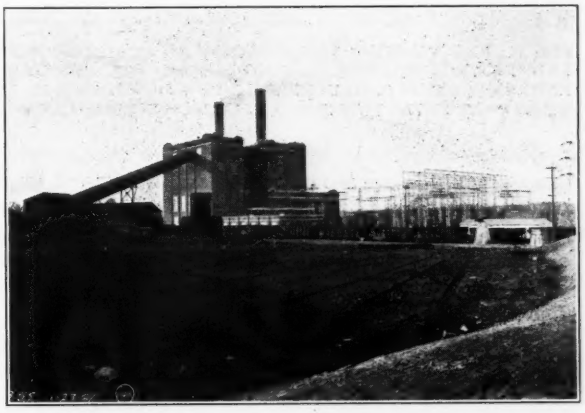


FIG. 3. COAL STORAGE FACILITIES AT A STANDBY CENTRAL STATION WHERE MOST OF THE COAL IS RECEIVED DURING THE SUMMER MONTHS

less of coal a week and efforts of these small consumers to obtain supplies during shortages have an effect on the market out of proportion to the actual tonnage used. The importance of the small consumer in any storage plan is obvious.

INDUSTRIAL PLANT STORAGE AVERAGES ABOUT 37 DAYS

Results of a study made by the U. S. Fuel Administration are shown in Fig. 1. This considers the country as a whole when, as a matter of fact, the stocks are not evenly divided. Figure 2 shows the supply of bituminous coal on hand at general industrial plants, other than steel and coke works, on October 1, 1928. These data, from the Bureau of Mines, show that at the rate of consumption prevailing in August and September industrial plants had enough coal to last 37 days. This reserve varied widely in the different states, with heavy reserves in New England and but a few days' supply in localities close to the mines. Locations of the major coal fields in relation to the electric power field as represented by the output of public utility plants are shown in

Fig. 4. The figures represent output from coal of utility plants in millions of kilowatt-hours during 1927.

These reserves change from season to season and from year to year, Fig. 5 showing the change in reserves of bituminous coal in the hands of commercial consumers from November 11, 1918 to October 1, 1928. This chart, from the Bureau of Mines, represents millions of net tons and includes coal in the hands of railroads, industrial consumers, public utilities and retail coal dealers.

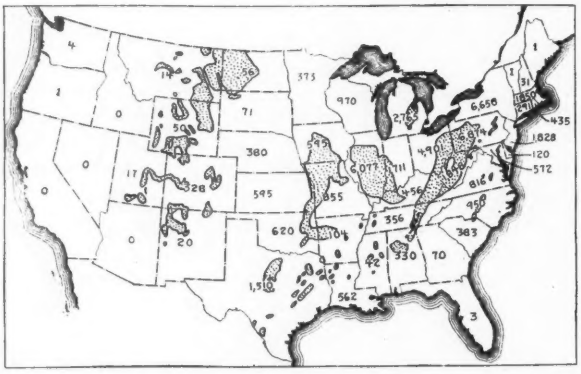


FIG. 4. MAP SHOWING DISTRIBUTION OF COAL DEPOSITS AND THEIR RELATION TO POWER MARKETS. FIGURES REPRESENT THE PRODUCTION OF POWER FROM COAL IN MILLION KILOWATT-HOURS, BY PUBLIC UTILITIES IN 1927

Reserves carried by various industries during about this same period are shown in Table I in terms of days supplies. In general, the figure of 37 days storage is representative of industrial plant practice while the electric utilities run somewhat higher and more irregular largely because they follow market and mine conditions more closely.

Variations of reserves in different sections of the country from figures collected by the Bureau of Mines are shown in Table II. Representative industrial and electric utility plants are given in detail with totals of the other industries added so that the relative importance of the several industries on the coal market can be studied.

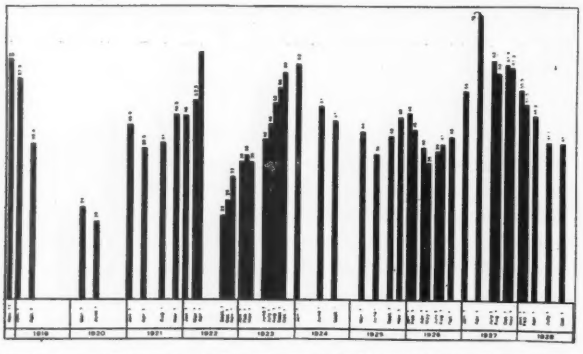


FIG. 5. TOTAL STOCKS OF BITUMINOUS COAL HELD BY COMMERCIAL CONSUMERS OVER A PERIOD OF TEN YEARS

Seasonal demand for coal, affected greatly by domestic consumption in the fall and winter months, causes difficulty in both production and transportation. Figure 7 shows the yearly variation in coal consumption of electric utilities and several representative industries, while Fig. 8 shows the production of bituminous coal at the mines for the past several years. The production for 1928 up to and including the week of November 17 was 430 million tons, with a weekly production of somewhat under 11 million tons.

This irregularity in coal production, as shown in Fig. 8, is due largely to seasonal demand. Since more coal is consumed in the fall and winter than in the spring and summer, coal producers and carriers are each year confronted with a period of demand followed by a period of no demand. It is estimated that seasonal demand is responsible for almost half of the idle time in the coal industry.

In addition, this condition of seasonal demand is largely responsible for over-development of mine capacity which is now about twice as large as the consumption capacity. To meet the heavy demands of the winter season, new mines are opened. This over-development or rather inordinate demand at certain seasons is a disadvantage to the consumer in that it is

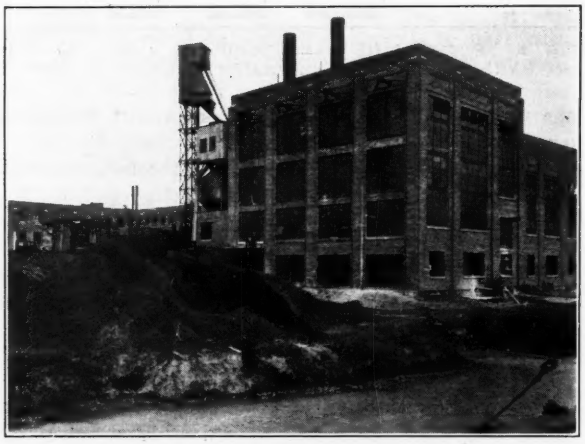


FIG. 6. COAL STORAGE AND HANDLING FACILITIES AT A REPRESENTATIVE MODERN INDUSTRIAL PLANT

usually necessary to accept low grade coal which he ordinarily would not do and it is also the cause of the short working year for the mine workers and mine owner. Both expect a full year's wages or profit for little more than two-thirds of a year's work. The public is called upon to pay this as the cost of over-development.

Fall Grain and Coal Shipments Conflict

Again transportation facilities of the United States are adequate for normal and regular movement of coal and for short periods they can move coal at a much greater rate although this is expensive and detrimental to the movement of other freight. Extraordinary demands for coal shipments in the fall conflict with grain and farm produce shipments at the same time, causing at times an apparent breakdown of transportation facilities and an active fuel shortage.

Both commerce and industry suffer serious interruption and grave losses from time to time because of coal shortages from one source or another. The coal industry is in an unstable and uneconomic condition. No one group interested in the production, consumption

or transportation of coal is responsible for these faults in the coal industry and no one group working alone can remedy them.

Coöperation by all three is necessary and this cooperation must be based on the realization by each group of the benefits which will result from this cooperation. In the end, it is the consumer who will profit most by improved conditions and conversely it is the consumer who has the most to lose by refusing to coöperate as, in the final analysis, it is the consumer who pays the additional costs brought about by this condition.

A fluctuating coal market is but one of the conditions with which industry is afflicted. An inadequate and inferior supply of coal is a serious matter in many processes and a curtailment of production means interruption of purchasing, production sales and fiscal plans. Furthermore, industry as a whole is vitally concerned in the proper functioning of the transportation system so that a stabilized load factor for the railroads is of great importance.

Overlapping as it does the fall agricultural shipments, the movement of fall coal has resulted in innumerable transportation delays which indirectly have cost industry much more than the actual direct cost of fluctuating coal prices.

TABLE I. DAYS' SUPPLY OF BITUMINOUS COAL CARRIED BY VARIOUS CLASSES OF CONSUMERS OVER A PERIOD OF YEARS

	Jan. 1 1919	Sept. 1 1925	Oct. 1 1926	Oct. 1 1927	July 1 1928	Aug. 1 1928	Oct. 1 1928a
By-product coke plants	32	22	26	40	23	25	27
Steel plants	42	30	37	58	38	34	31
Coal-gas plants	81	67	70	93	63	66	72
Coal dealers (Bituminous)	39	27	32	43	43	34	33
Railroads	32	28	33	48	37	35	29
Other industrials	65	38	37	62	37	38	37
Electric utilities	49	43	45	69	62	56	56
Total bituminous	42	32	35	53	38	36	35

(a) Calculated at average rate of consumption during August and September

TABLE II. REGIONAL ANALYSES OF BITUMINOUS COAL STOCKS AND TREND OF CONSUMPTION BY VARIOUS INDUSTRIES

District and class of consumer	Number of plants reporting	Days supply in stock		Trend of consumption		
		Oct.1, 1927	Oct.1 1928	Net tons consumed Aug.-Sept. 1927	Net tons consumed Aug.-Sept. 1928	Per cent of change
Representative Industrials						
1. New England	429	111	72	551,185	511,314	7.2
2. Middle Atlantic	423	65	37	2,121,305	1,893,917	10.7
3. Ohio	128	59	23	953,326	991,603	4.0
4. Southern Michigan						
5. Illinois - Indiana	210	37	25	1,185,794	1,303,758	9.9
6. Lower Missouri Valley	122					
7. Lake Dock Territory	162	104	96	521,320	492,602	5.5
8. Southeast	323	38	28	795,864	713,438	10.4
9. Southwest Mountain and Pacific	136	38	36	281,484	272,868	3.1
Electric Utilities						
1. New England	62	104	74	461,194	454,051	1.5
2. Middle Atlantic	150	62	44	2,294,811	2,317,501	1.0
3. Ohio	85	126	70	643,117	733,351	14.0
4. Southern Michigan	37	129	111	359,820	394,221	9.6
5. Illinois - Indiana	116	51	41	1,253,925	1,358,371	8.3
6. Lower Missouri Valley	164	34	37	445,168	448,385	0.7
7. Lake Dock Territory	117	115	98	271,326	253,582	6.5
8. Southeast	158	37	55	995,096	591,641	40.5
9. Southwest Mountain and Pacific	97	31	76	349,887	209,329	11.6
Other Industries - All Districts						
1. By-product coke plants	80	40	27	10,473,049	11,443,704	9.3
2. Beehive coke plants				1,489,000	946,000	36.5
3. Coal-gas works b	214	93	72	557,516	592,545	6.3
4. Steel plants	200	58	31	2,834,287	2,919,925	3.0
5. Representative retail yards	861	43	33	2,617,569	2,586,333	1.2
6. Locomotive fuel	156	48	29	14,743,047	14,404,988	2.3
7. Foreign bunkers				806,000	749,000	7.1
8. Representative Industrials	2,015	62	37	7,286,178	7,338,108	0.7
9. Electric utilities	986	69	56	7,074,344	6,860,432	3.0

Consumer Can Work Individually

Seasonal storage is a simple, direct and practical remedy for this situation and by it the consumer can eliminate, individually, any interruption in connection with the quantity and quality of his coal supply. General adoption would result in a stabilized condition of the coal and transportation industry, although, without some directing influence or national emergency, it is doubtful whether any concerted action can be expected.

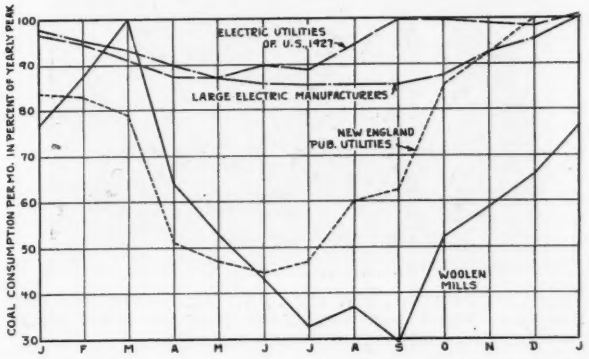


FIG. 7. CHART SHOWING HOW THE COAL CONSUMPTION OF REPRESENTATIVE INDUSTRIES VARIES THROUGHOUT THE YEAR

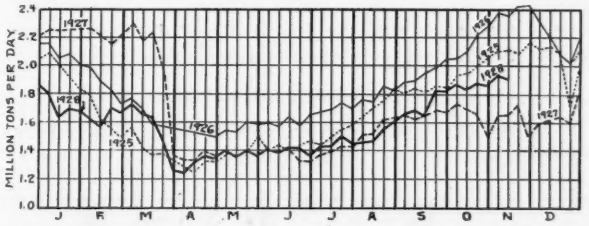


FIG. 8. PRODUCTION OF BITUMINOUS COAL SHOWS A DECIDED DROP DURING SUMMER MONTHS

Coal reaches the markets by three general methods: first, all rail; second, rail to tidewater and then by barge or boat to foreign or coastwise ports; third, by rail to the Great Lakes, thence by boat to upper lake ports and then by rail to the interior markets. As can be seen from Table II, the railroads use approximately a quarter of the total production.

As such, they as a class, have more to gain by storage than any other single industry and they should, and do to a certain extent, store the coal for their own use in such amounts, at such a time and in such locations as to reduce to a minimum the necessity for moving their own coal, which is non-revenue producing, during periods when there is a heavy demand for cars to transport revenue producing freight.

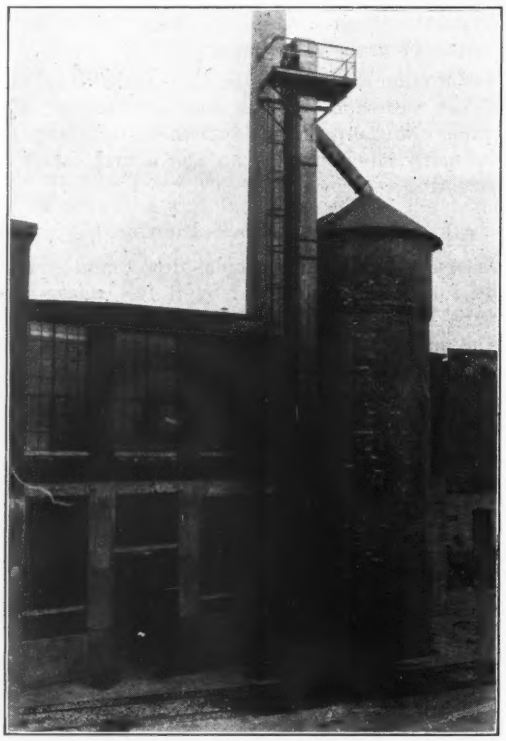


FIG. 9. SILOS FOR BOTH LIVE AND DEAD STORAGE ARE POPULAR WITH THE SMALLER PLANTS, ESPECIALLY WHERE SPACE IS LIMITED

To accomplish the most in relieving transportation and production difficulties, storage should take place at or near the point of consumption, although conditions may make mine or intermediate storage desirable. In general, mine storage sufficient to take care of ordinary operating delays such as delays in car arrivals, breakdowns or temporary labor troubles, should be provided.

Dealers Are of Assistance to Small Buyers

Under the prevailing practice, coal is shipped by three general routes: direct to the consumer for intermediate use or storage, direct to adjacent mine storage or central storage for producers or to storage adjacent to the consumer. Buildings, available space, taxes and insurance are often limiting factors in storage of small industrial plants and seriously affect the amount of coal stored. Dealers often fill an important function in relation with these small plants, sometimes making arrangement to store coal in a certain portion of the yard or keeping a certain tonnage on hand to act as a reserve supply.

After a thorough study of the coal and coal storage situation a few years ago, a special committee of the American Engineering Council recommended the purchase of coal on an annual contract for the yearly requirements with provision that the coal be delivered in equal monthly allotments. This, of course, means provision for a certain amount of seasonal storage.

It was felt that this would allow the mines to maintain a regular production schedule and allow the carrier to plan definitely for shipping schedules and equipment. During the months from April to September, coal would automatically accumulate in sufficient amount to meet the extra consumption during the winter months. This should result in a reduction in the price of coal by eliminating the expensive peak demands of the winter months. Bituminous coal constitutes roughly a third of the total tonnage of railroads and an excess coal movement of 20 per cent, coming when crop shipments are heaviest, can materially unbalance traffic.

TABLE III. TABULATION SHOWING THE ACTUAL COAL IN AND OUT OF STORAGE OVER A PERIOD OF ONE YEAR IN CHICAGO

Month	Consumption	Storage		Actual Shipments
		Into	Out of	
Apr.	359,000		115,300	243,700
May	336,800		110,200	226,600
June	315,500		43,800	271,700
July	326,100		125,400	200,700
Aug.	327,900		87,800	240,100
Sept.	358,500	50,800		409,300
Oct.	402,800	91,100		493,900
Nov.	421,600	43,700		465,300
Dec.	455,200	67,100		522,300
Jan.	462,500	94,100		556,600
Feb.	424,400		32,000	391,400
Mar.	448,300		34,100	414,200
Total	4,638,600	346,800	549,600	4,435,800
Av. Consumption-386,550- Uniform Shipment				

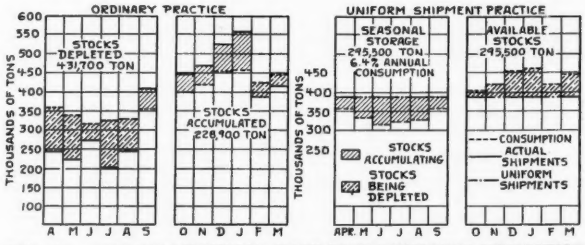


FIG. 10. CHART SHOWING HOW THE UNIFORM SHIPMENT PLAN WOULD IMPROVE CONDITIONS IN THE CHICAGO AREA

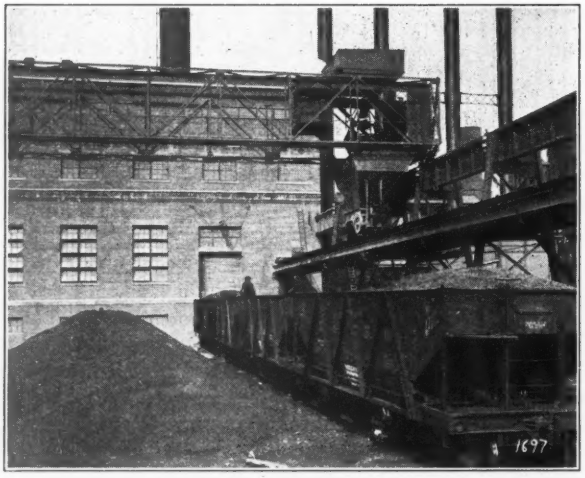


FIG. 11. BECAUSE OF THE LARGE QUANTITY OF COAL HANDLED, STORAGE FACILITIES IN CENTRAL STATIONS ARE USUALLY MORE ELABORATE THAN IN INDUSTRIAL PLANTS

This method taken nationally would result in the minimum amount of storage for the shortest period of time to accomplish the desired result and would actually mean less storage than has been demonstrated as available. To accomplish this result, however, there must be a wider distribution of such storage facilities.

The effect of such a uniform storage system upon monthly coal deliveries is shown in Fig 10, drawn from data in Table III. These data are complete for 14 representative Chicago industries and represents about 15 per cent of the total estimated annual coal consumption of about 31,000,000 t. for Chicago.

As a result of national studies of the committee mentioned above, the recommendations shown in Table IV are representative of good practice in different parts of the country. These recommendations must, of course, be used with discretion, as the recommendations are based on but a few cases which may or may not be representative. The transportation factor, that is, the distance from the mine and railroad facilities were not considered and the statistics were based on a single year's record and that may not have been normal for all conditions and industries.

It should be noted, however, that of the cities shown, only the first 9 fall outside of the range 10 to 21 per cent proposed for the country as a whole. Within this range of 10 to 21 per cent, of which 16 to 17 per cent is the mean, fall 28 of the 40 communities from which data was gathered.

For the six communities with a higher than average storage factor, the consumption is exceptionally irregular while for the three communities with a lower than average factor the consumption is unusually regular. Factors recommended should, of course, be taken only as indicating a general figure for each community and not as a precise percentage to be closely followed.

To summarize, coal storage is advantageous, first, to assure an adequate supply of fuel at all times in spite of strikes, shortages or transportation delays; second, to take advantage of low freight rates or low coal prices at certain seasons of the year, by permitting the railroads to utilize their equipment to the best advantage and helping to maintain uniform production at the mine. The first is an insurance against fuel shortage and as such will probably increase the unit cost of fuel slightly while the second tends to reduce unit costs by an improvement of an economic structure of the country as a whole.

TABLE IV. TABULATION SHOWING HOW COAL STORAGE UNDER THE UNIFORM SHIPMENT PLAN WOULD VARY IN DIFFERENT SECTIONS OF THE COUNTRY

City	No. of consumers represented	Annual consumption tons	Percent of Annual Tons Proposed Storage		
			Reserve	Seasonal	Total
Birmingham	4	52,300	7.0	28.0	35.0
Seattle	5	252,800	7.1	16.9	24.0
Buffalo	7	262,700	7.4	16.1	23.5
Detroit	21	2,657,800	7.0	16.4	23.4
Salt Lake City	15	96,900	7.0	16.0	23.0
Worcester	32	343,900	7.4	14.6	22.0
Minneapolis	34	674,100	7.2	13.8	21.0
New Haven	13	493,200	7.3	13.2	20.5
Schenectady	11	403,100	7.3	13.2	20.5
Columbus	10	119,000	7.1	12.9	20.0
Dayton	10	368,200	7.2	12.8	20.0
St. Louis	9	1,511,800	7.0	13.0	20.0
Meriden	46	115,200	7.1	12.4	19.5
Pittsfield	7	103,800	7.3	12.2	19.5
Washington	12	520,700	7.4	11.6	19.0
Indianapolis	9	685,200	7.4	11.1	18.5
Hartford	26	211,200	7.5	10.5	18.0
Waterbury	10	219,900	7.1	10.9	18.0
Atlanta	5	417,400	7.4	10.1	17.5
Duluth	23	121,800	7.4	9.6	17.0
Rochester	11	64,000	7.2	9.8	17.0
Baltimore	6	503,000	7.3	8.7	16.0
Boston	8	1,244,700	7.1	8.9	16.0
Lynn	16	338,100	7.2	8.8	16.0
Vulcan	21	175,900	7.3	8.2	15.5
Cincinnati	12	660,400	7.1	7.9	15.0
Akron	18	1,135,200	7.0	8.0	15.0
Fort Wayne	5	178,000	7.0	8.0	15.0
Syracuse	7	68,300	7.3	7.2	14.5
Lehigh Valley	7	1,617,800	7.4	6.6	14.0
Chicago	14	4,638,600	7.1	6.4	13.5
State	20	405,900	7.4	5.6	13.0
New York City	17	3,492,900	7.3	5.2	12.5
Providence	7	395,700	7.0	5.0	12.0
Grand Rapids	7	98,000	7.4	4.2	11.6
Omaha	5	241,900	7.2	3.8	11.0
Philadelphia	10	1,342,300	7.2	2.8	10.0
Knoxville	11	89,800	7.4	2.4	9.8
Richmond	2	179,500	7.4	2.4	9.8
Denver	3	127,000	7.4	2.1	9.5
Overall Per cents 530		26,708,100	7.2	9.1	16.3

Deterioration and Combustion in Stored Coal

WEATHERING CAUSES COMPARATIVELY SMALL LOSS. SPONTANEOUS COMBUSTION MAY GIVE MUCH TROUBLE UNLESS PROPER PRECAUTIONS ARE TAKEN

IN THE STORING of coal for power plants, as discussed in the preceding article, certain difficulties are encountered which may cause more trouble in some cases than they do in others. These difficulties are: deterioration or loss of heating value due to weathering; degradation or undesired breaking of the coal; spontaneous combustion, causing fires in the coal below the surface of the pile.

LOSS DUE TO DETERIORATION

In some cases, deterioration may cause an appreciable loss in heating value of the coal but in most cases, it is not considered large enough to cause a loss in monetary value great enough to preclude storage of coal. The percentage of heat lost by deterioration will seldom exceed 5 per cent even with sub-bituminous coal and with other coals it averages much less than that. Tests on Illinois nut coal have shown from 3 to 3½ per cent loss in heating value in one year in outside storage, while screenings had a loss as high as 5.14 per cent.

DETERIORATION OF VARIOUS TYPES OF COAL

Tests made by the U. S. Bureau of Mines on various other types of coal have shown comparatively small losses, as reported in the accompanying table. New River coal, tested in outside storage, showed loss of heat value of about 1 per cent in the first year, 2 per cent in the first two years, and not over 3 per cent in five years. Pittsburgh gas coal in open-air storage showed practically negligible deterioration in the first year and the loss then proceeded slowly, not exceeding 1.1 per cent in 5 yr.

Tests on Sheridan, Wyo., coal by the C. B. & Q. Railway Co. showed heat loss of 3 to 5.5 per cent in 2¾ yr. in open storage. It was thought that by using enclosed storage this could be reduced. There was no evidence of heating during the tests of this sub-bituminous coal but it was felt by the observers that it would be dangerous to store Sheridan coal to depths of more than 10 ft.

In connection with the above-mentioned tests of New River coal, the Bureau of Mines stated that simultaneous tests of samples under sea water and in open storage showed that submerged storage of New River coal was not necessary for the sake of preventing deterioration of heat value and that its advantage lay only in preventing spontaneous combustion.

Some coals, on exposure to the weather, become covered with a frost-like film of white iron sulphate. This is not a sign of deterioration, according to Parr, since only a portion of the sulphur has been oxidized to the white sulphate and this is dissolved and washed away by rain water. While the ash content may thus be lowered slightly, it is only a surface effect.

TABLE SHOWING HEAT LOSS OF VARIOUS TYPES OF COAL BEFORE AND AFTER STORAGE, CALORIFIC VALUE IN CALORIES

Kind of coal.	Storage conditions.	Place.	Calorific value.				
			As stored.	After 3 months.	After 1 year.	After 2 years.	Per centage of loss in 2 years.
New River, W.Va.[a]	¼-inch coal, under sea water.	Portsmouth, N. H..	8,761	.....	8,759	8,730	[b]0.39
		Norfolk, Va.....	8,754	.....	8,763	8,737	[b].46
		Key West, Fla.....	8,747	.....	8,732	8,770	0
	¼-inch coal, under fresh water.	Pittsburgh, Pa.....	8,752	8,762	8,749	8,760	0
	¼-inch coal, exposed to air indoors.	Portsmouth, N. H..	8,779	8,738	8,742	8,709	.80
		Norfolk, Va.....	8,751	8,742	8,736	8,717	.39
		Key West, Fla.....	8,754	8,728	8,676	.....	.....
		Pittsburgh, Pa....	8,769	8,736	8,719	8,720	.56
	R. o. m. coal, exposed to air indoors.	Portsmouth, N. H..	8,754	8,758	8,748	8,734	.23
		Norfolk, Va.....	8,743	8,764	8,725	8,725	.21
		Key West, Fla.....	8,745	8,733	8,710	.....	.....
		Pittsburgh, Pa....	8,753	8,758	8,740	8,743	.11
	¼-inch coal, exposed to air outdoors, uncovered.	Portsmouth, N. H..	8,741	8,730	8,701	8,674	.77
		Norfolk, Va.....	8,726	8,709	8,666	8,625	1.16
		Key West, Fla.....	8,739	8,721	8,680	8,592	1.85
		Pittsburgh, Pa.....	8,763	8,726	8,700	8,665	1.12
	R. o. m. coal, exposed to air outdoors, uncovered.	Portsmouth, N. H..	8,775	8,766	8,760	8,722	.60
		Norfolk, Va.....	8,743	8,745	8,720	8,695	.55
		Key West, Fla.....	8,752	8,708	8,722	8,632	1.39
		Pittsburgh, Pa.....	8,752	8,740	8,716	8,696	.64
Pocahontas, Va.....	130-ton pile, r. o. m. coal, outdoors.	Panama.....	8,794	8,787	8,762	.....	.....
Pittsburg bed.....	4 tons r. o. m. coal in open bin, outdoors.	Ann Arbor, Mich....	8,541	[c]8,539	8,526	.....	.....
			8,541	[d]8,553	8,528	.....	.....
Sheridan, Wyo., subbituminous.[e]	R. o. m., open bin 5 ft. deep.	Sheridan, Wyo.....	7,370	7,174	.....	7,135	[f]3.19
	R. o. m., closed bin 5 ft. deep.	.....do.....	7,370	7,202	.....	7,094	[f]3.75
	R. o. m., closed bin 15 ft. deep.	.....do.....	7,370	7,303	.....	6,982	[f]5.26
	Slack, closed bin 15 ft. deep.	.....do.....	7,355	7,166	.....	6,990	[f]4.96

[a] Heating value of representative mine sample of coal (ash, moisture, and sulphur free), 8,765 calories.
[b] On basis of original heating value of same test portion.
[c] After six months' storage, entire lot in bin.
[d] After six months' storage, upper 6 inches at surface of bin.
[e] Each bin contained 5 to 10 tons.
[f] After two years and three-quarters.

Breaking of Coal

Degradation or breakage of coal takes place with every handling and efforts should be made to minimize this breakage, especially if the coal is to remain in storage for a considerable time. This breakage produces some fine coal that has its effect on spontaneous combustion. Alternate wetting and drying, freezing and thawing of the coal also break it up. Most degradation, however, is caused by the handling it receives.

Spontaneous Combustion Causes Most Concern

By far the greatest source of loss in stored coal is by spontaneous combustion. This loss may be so high that great care is justified in taking measures to prevent it. When coal is properly stored, fires due to spontaneous combustion are rare.

Fires in coal storage piles due to spontaneous combustion are influenced by several factors: (1) character of coal in regard to volatile matter; (2) purity of coal; (3) presence of pyrite or other sulphur compounds; (4) temperature of coal; (5) size of coal; (6) pressure of occluded gases in coal; (7) moisture in coal; (8) accessibility of oxygen; (9) pressure on coal.

Only those coals containing large amounts of volatile are liable to ignite spontaneously; anthracite, with its low volatile, is practically free from this liability.

Influence of Sulphur

Opinions differ as to the influence of pyrite and other sulphur compounds on spontaneous combustion. Some authorities state that the reaction between sulphur and oxygen is a positive source of heat but here again the rapidity of the reaction is dependent upon the fineness of division.

Recent researches have led to the belief that the carbon dioxide formed from oxidation of the coal itself has in its turn an affinity for the coal and that in the absorption of this CO_2 by the coal further heat is generated.

Heat may be conducted into the pile by rails, pipes or structural work and it is believed that even the heat of the sun has been responsible for some spontaneous combustion. Even a small increase in temperature, whether from outside sources or from reactions in the coal, tends to accelerate the absorption of oxygen and drive out inflammable occluded gases.

Fine Coal Is Harder to Store

Fine coal is a more active absorbent of oxygen than large coal and more care is needed in storing it. Some observers even go so far as to discourage the storing of fine coal. Segregation of the coal in piling it should be prevented, if possible, for this reason.

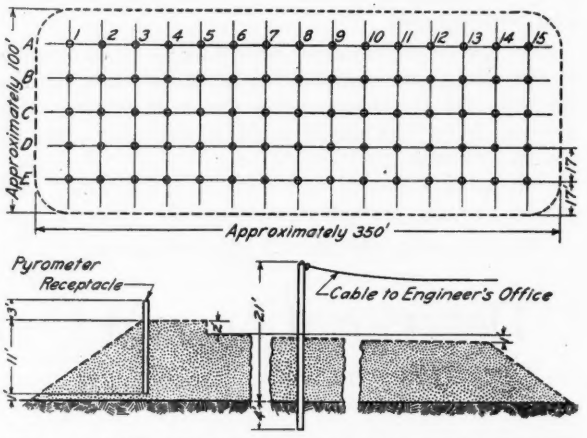


FIG. 1. PLAN AND SECTION OF COAL PILE SHOWING RECEPTACLES FOR PYROMETERS

Presence of moisture assists the pyritic oxidation and aids the mechanical disintegration by alternate freezing and thawing. Opinions differ greatly as to the effects of moisture but it is generally agreed that it has an important role in one way or another.

Combination of oxygen with the constituents of the coal, it seems to be agreed, causes a rise in temperature. Which particular constituent is the cause of the rise in temperature has not, however, been shown with any degree of certainty. It is agreed, however, that oxygen (or air) is to be excluded wherever fine coal is involved. Segregation of the coal in piling furnishes avenues through the large lumps by which oxygen can reach the fine material within.

Pressure on the coal is believed by some to be responsible for heating in the pile and because of this they advocate that piles should not be higher than 15 to 20 ft.

In storing coal, the methods of piling must be such as to carry off the heat caused by the chemical reactions or to prevent all air from filtering through the pile. In many cases of heating, the hot spots seem to occur from 5 to 8 ft. from the exposed surface of the pile. It would appear that the fire hazard is independent of whether the pile is under cover or in open space.

Detecting Excessive Heat in Coal Pile

Detection of excessively high temperatures can be carried out as follows:

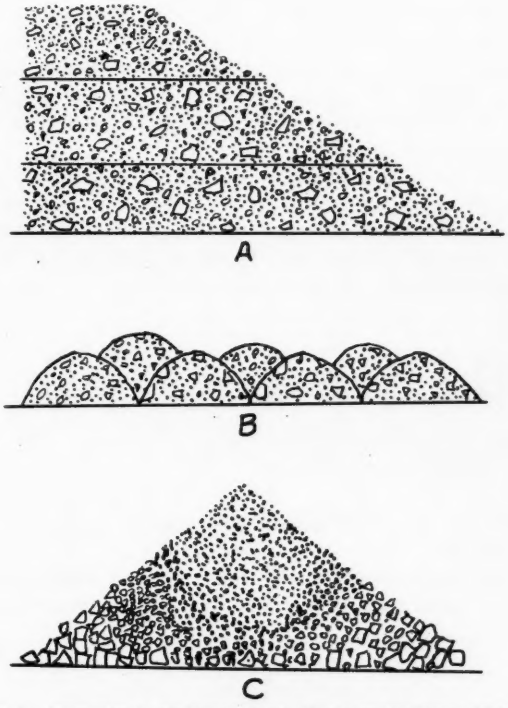


FIG. 2. METHODS OF PILING COAL TO PREVENT SEGREGATION. A—CORRECT METHOD OF PILING COAL; LUMPS AND FINES WELL MIXED IN 2-FT. LAYERS. B—CORRECT METHOD OF DUMPING COAL; LUMPS AND FINES WELL MIXED. C—INCORRECT METHOD OF STACKING COAL, LUMPS AND FINES BEING ALLOWED TO SEGREGATE

1. By watching for evidences of steaming in the pile.

2. By noting the odor given off; bituminous or sulphurous odors are evidence of heating.

3. By noting places where snow on a pile has melted.

4. By inserting an iron rod in the pile and noting its temperature with the hand after removal.

5. By inserting thermometers or thermocouples in the pile.

Figure 1 shows a common method for inserting portable pyrometers in a large storage pile, the readings being taken on the instruments in the engineer's office.

If the temperature at any point in a pile gets as high as 140 deg. F., it should serve as a warning. If it increases to 150 or 160 deg., the coal should be moved and spread out to cool. At 180 deg., bituminous coal will begin to smoke and spontaneous combustion is imminent.

Two general theories have influenced the methods of open storage. One of these theories is that there should be a sufficient circulation of air through the pile to carry off the heat of oxidation at low temperatures as fast as it is formed. For this purpose, ventilating ducts have been used by some companies with considerable success.

Preventing Fires by Excluding Air from Pile

General practice nowadays and in this latitude is based, in many cases, on the theory of excluding as much air as possible from the pile. There are so many variables, however, that extreme care in piling is necessary, with constant inspections for three or four months after the pile is put down.

Since kindling is a common source of ignition, care must be used in forming the bottom of the pile. Kindling consists of rags, timbers, old coal left from a previous pile and so on. Moisture on the ground should be guarded against also. To do this, many companies either cover the ground with cinders and roll them down or else a concrete floor on which to pile the coal. Drains for moisture should be provided around the edge of the pile but not under it.

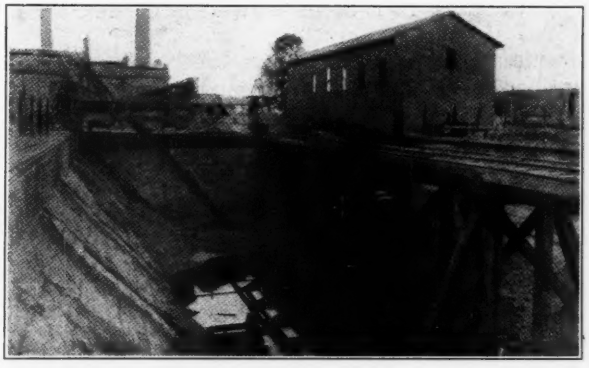


FIG. 3. STORAGE PIT OF 5000-T. CAPACITY FOR STORING COAL UNDER WATER

Packing Coal to Exclude Air

For excluding air from the pile, many companies are packing the coal. In some cases, the coal is spread in layers with a tractor, which then drags a roller to roll down the pile. In other cases, layers 1½ or 2 ft. thick are put down by a bucket and then rolled. A third method uses a large flat tamping weight, dropped by a locomotive crane all over successive layers. Piling in layers in this way is also of great assistance in preventing segregation. If the pile must be formed with a bucket crane, segregation can be lessened somewhat by having the bucket lowered to rest on the pile before being opened, depositing the coal in pyramids.

Coal can be placed in layers by wheeling it in barrows, spreading the loads adjacent and then wheeling the next layer on planks, thus practically laying the coal on the pile. The same method can be used with wagons.

Storage of coal under water has been demonstrated

an effective way of preventing spontaneous combustion, as all air is excluded. A pit for under water storage is shown in Fig. 3. Storage of coal in silos has also been

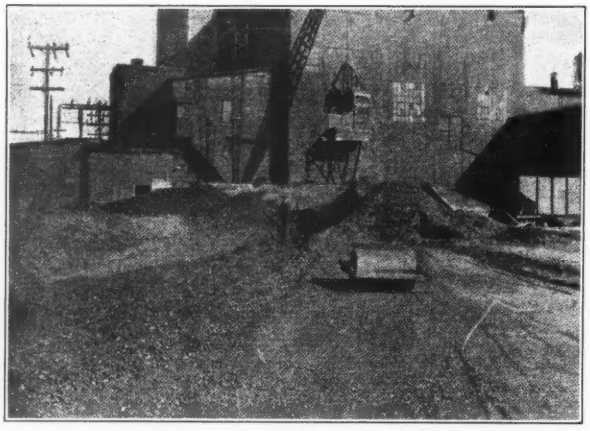


FIG. 4. ROLLING LAYERS OF COAL. DRAGLINE BUCKET DEPOSITS LAYERS 17 IN. THICK WHICH ARE THEN ROLLED TO 13 IN. BY A TWO-TON ROLLER

practiced extensively and these have sometimes been equipped with water or steam piping so they can be flooded in case of fire.

Methods of Extinguishing Coal Pile Fires

Coal piles should be arranged so that any part of the pile can be moved if it catches fire or overheats. Heated coal that has to be moved should be spread out thinly in an airy place away from buildings where, if it should burst into flame, it will not endanger property.

Hot coal in a pile must be handled carefully as it may burst into flame on being moved. A good supply of water should be at hand in case flame does break out. Water must be used only as a last resort, in case moving does no good and then only when it is possible really to flood the affected part. Surface wetting does little good; it may merely form a wall of coke and prevent the water from reaching the burning part. A hole may sometimes be dug in the pile above the burning part and used as a funnel for copious applications of water. Sometimes fires have been effectively flooded out by driving pipes down into the pile about the fire zone and forcing water down them. Use of water is not always successful in extinguishing fires, as it may cause formation of steam, water gas, or a coke shell surrounding the fire that stops infiltration of moisture.

When a heated pile is to be moved, the job must proceed systematically, rapidly and without cessation until the burning parts and any of the surrounding heated coal is moved. This often means moving two or three times the amount of coal that is on fire.

Space Requirements in the Storage of Coal

Inside and Outside Storage. Bunker Storage, Silos. Height of Piles in Open Storage. Arrangement of Piles

SPACE REQUIREMENTS for the proper storage of coal vary widely at different power plants and no exact rule or formula can be given which will give the correct solution to the coal storage problem for all plants. A number of factors enter into the question, some of which in themselves are vague and are more often matters of common sense than mathematical calculation. Much depends upon past experience and no designer is justified in undertaking the design of coal storage facilities until he has carefully investigated existing systems in plants similar to his own.

Storage of coal in power plants falls under two general classifications: first, storage in bunkers, for the immediate requirement of operation; second, an outside storage of some type of considerably greater capacity to satisfy the plant's needs over a comparatively long period of time.

In small plants purchasing coal from local dealers who keep large stocks on hand, outside storage is not always necessary or feasible. This applies particularly to industrial power plants in cities where space is at a premium and where none is available for outside storage. In such plants, the entire storage is in the boiler house bunkers. It must be obvious that where these conditions exist, the boiler house bunkers must be considerably larger than in a plant having an outside reserve. It is usual in such plants to provide space for from 7 to 10 days' supply of coal. Where outside storage is provided, however, the boiler house bunkers need not, as a rule, have a capacity for much over 24 hr. supply.

Outside storage usually takes care of much larger quantities of coal. For central stations, the reserve coal

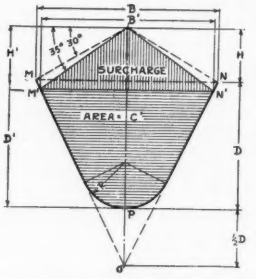


FIG. 1. CROSS SECTION THROUGH SUSPENSION BUNKER

pile ranges from 10,000 to 200,000 t. or more, sufficient, in many instances, to insure from 3 to 6 months' supply.

In general, the amount of space required for the bunkers in the boiler house depends: 1. Upon the capacity of the plant. 2. Upon the rate at which the coal is burned. 3. Upon the reliability of transportation facilities delivering coal to the plant. 4. Upon whether or not outside storage is provided.

Knowing, from a careful consideration of the foregoing factors, approximately how much coal it is desired to keep on hand in the bunkers, the determination of the actual space required in the boiler house is a simple

matter of arithmetic. Several different types of bunkers are in use, the overhead steel bunker of curved or elliptical section being the most common in medium sized plants. This type of bunker, usually suspended over the firing aisle, occupies space that ordinarily cannot be used advantageously for other purposes and permits of feeding directly to the stokers by means of

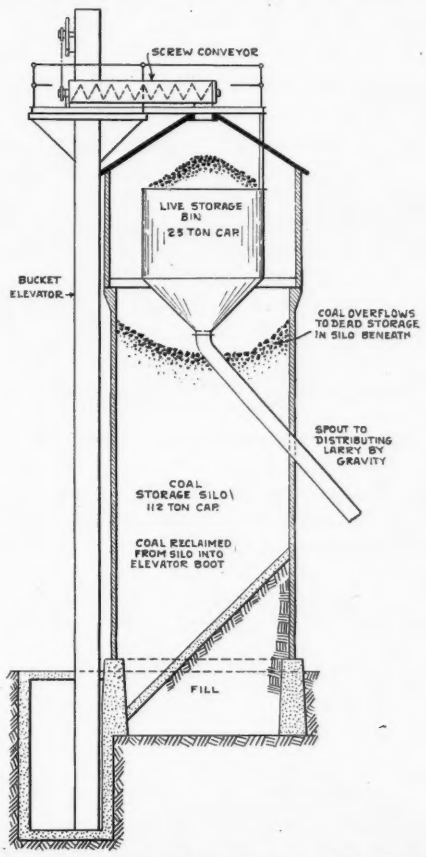

SCREW CONVEYOR
LIVE STORAGE BIN
25 TON CAR
BUCKET ELEVATOR
COAL OVERFLOWS TO DEAD STORAGE IN SILO BENEATH
SPOUT TO DISTRIBUTING LARRY BY GRAVITY
COAL STORAGE SILO 112 TON CAP.
COAL RECLAIMED FROM SILO INTO ELEVATOR BOOT
FILL

FIG. 2. SECTION THROUGH THE SILO SYSTEM AT MILWAUKEE CHAIR CO.

spouts. Where a considerable quantity of coal is to be stored in the boiler room the overhead bunker has much to recommend it.

A typical cross section of a suspension bunker is shown in Fig. 1. For any given values of width B and depth D, regardless of the weight of contained material or the ratio of B to D, a close approximation of the correct tension curve is given by this design. Locate O on the center line of the bunker at a distance 1½ D below the top, NM. Draw the lines MO and NO. Locate P on the center line at the desired depth D. Draw a circular arc tangent to MO and NO, and passing through P. The outline MPN is close enough to the ideal tension curve for detailed design, as well as for estimating. The capacity below the line MN in cubic feet per foot of length is

$$C = \tfrac{5}{8}BD$$

The capacity per foot of length in tons of coal at 50 lb. per cu. ft. is

$$T = \frac{BD}{64}$$

Where bunkers are required to carry a surcharge, use 30-deg. slopes from M to N to determine the maximum loading height H so as to prevent overflow and use 35-deg. slopes from the peak so located to calculate the storage capacity which will be

$$C' = \tfrac{5}{8}B'D' + \text{surcharge volume}$$

or

$$T' = \frac{B'D'}{64} + \text{surcharge tonnage}$$

Silo Storage System

A system of coal storage for small and medium sized plants that has come into vogue during recent years is the silo system. This embraces a complete storage and reclaiming system consisting of a silo built of hollow tile, concrete, brick or steel, together with a suitable conveying system.

FIG. 3. EXTERIOR VIEW OF SILO SYSTEM AT MILWAUKEE CHAIR CO.

In Fig. 2 is shown a cross section through a typical silo system, that used at the plant of the Milwaukee Chair Co., Milwaukee, Wis. As will be noted, a steel "live storage bin" of 25-t. capacity is suspended in the upper part of the storage silo which is filled by means of the bucket elevator and the screw conveyor. When this live storage bin has been filled, the excess coal overflows into the reserve storage below, where it falls by gravity into the elevator boot.

As the live storage bin at the top of the silo is emptied through the spout leading to the boiler room,

it is refilled by means of the bucket elevator which draws coal from the bottom of the silo and transfers it to the live storage bin. An exterior view of this installation is shown in Fig. 3. This plant burns sawdust which is fed from the steel bin at the right of the silo.

This system is flexible and by the use of two or more silos together, can be applied to plants of considerable size. An installation using two silos served by a single bucket elevator is shown in Fig. 4. This is the system

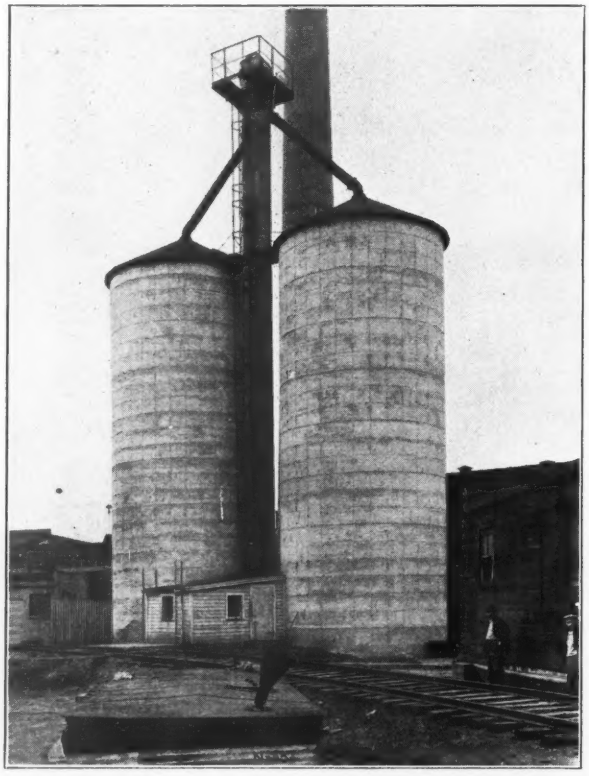


FIG. 4. SILO SYSTEM AT THE PLANT OF THE AMERICAN STOVE CO.

installed at the plant of the American Stove Co. at Harvey, Ill. The bins in this case are of concrete and have a combined storage capacity of 700 t. and a handling capacity of 20 t. per hr.

Open Storage

Several methods are available for the storage of coal outside of the power plant, the most common being the open storage method in which the coal is merely piled up in a storage yard directly exposed to the elements. To protect the coal from the action of the elements to which the open pile is exposed, coal is often stored under water. In this case, it is stored in pits flooded with water and is removed by means of grab buckets. This method is extremely effective in preventing deterioration, but because of the greater expense involved in constructing and waterproofing the pits, is not used to any considerable extent.

The open type of coal is used by nearly all of the public utility plants and most of the industrial plants in existence today. The amount carried in storage varies widely; from 10,000 t. in small plants to 200,000 or 300,000 t. in large plants. Where large public utility companies operate large stations in metropolitan districts, where space for storage adjacent to the stations is limited, one central storage yard for the entire system is often maintained at a point some distance (5 to 40 mi.) away from the stations where it is used. This is the practice of the Philadelphia Electric Co., which maintains a storage of some 225,000 t. on Pettys Island, a short distance down the Delaware River from Philadelphia. Separate smaller storage piles are maintained at the plants in Philadelphia, but the bulk of the storage is on the Island.

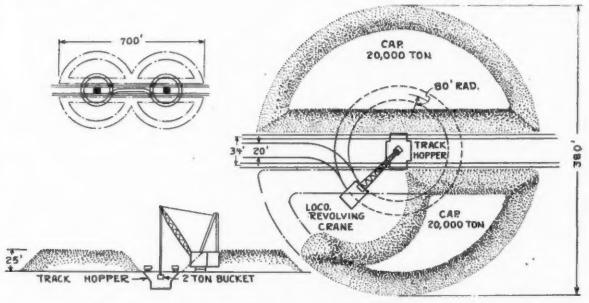


FIG. 5. CIRCULAR STORAGE SYSTEM

At the Hudson Ave. Station, also, it was impossible to secure a lot sufficiently large to provide adequate storage at the station, so a 200,000-t. yard is provided at Ramsville, L. I.

Wherever possible, however, it is advisable to have the storage pile located adjacent to the power station so as to obviate the necessity for rehandling.

For open storage with small plants, the use of the portable bucket hoist or wagon loader driven by an

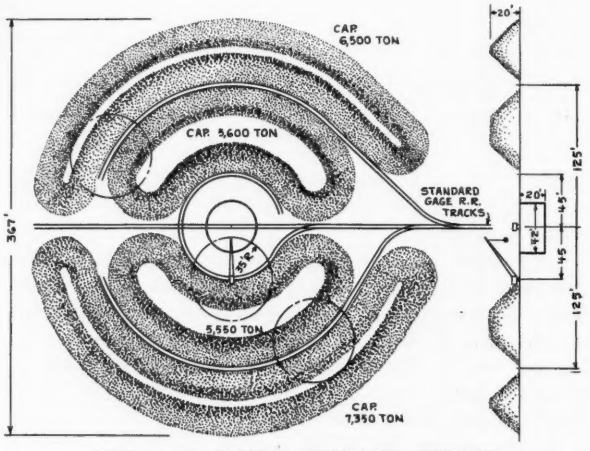


FIG. 6. A 25,000-T. STORAGE SYSTEM

electric or gasoline motor, which can be moved along the storage piles as the coal is laid down or delivered, has proved satisfactory and economical. In storage piles handled by this method, it is common practice to stock in relatively low piles. A maximum depth of 16 to 18 ft. with an average of 10 ft. throughout the entire storage space is good practice. Allowing 50 cu. ft. per ton, there will be required 5 sq. ft. of land per ton, or an area 50 by 100 ft. for storing 1000 t. An area of this size can also be served by a rail trestle.

Larger areas or storage piles of greater capacities are handled by a number of different methods, each of which have their own peculiar merits. These methods, the drag scraper system, use of locomotive cranes, are more fully described elsewhere in this issue.

For large storage, except where extremely large special equipment is necessary, the revolving locomotive crane equipped with clam shell bucket is popular. Still larger storages use the bridge crane or the drag scraper system.

Among the various forms of coal piles used in storing coal in the open, the circular storage shown in Fig. 5 has proved successful where the locomotive crane is used. The system depicted in Fig. 5 is adaptable to storing coal up to 40,000 tons. The coal is dumped from a railroad car into a track hopper from which it is taken by a long radius locomotive crane and dumped upon piles, the circular crane track being completely covered. Two 20,000-t. piles, one on each side of the track, it will be noted, occupy a circular area 380 ft. in diameter. The coal is piled to a height of 25 ft.

Where greater capacity is required, two such systems can be used together, one slightly overlapping the other. This gives a storage capacity of approximately 75,000 t. in a space 700 ft. long by 380 ft. wide.

An elaboration of this system by which concentric storage piles may be built up is shown in Fig. 6. By rehandling the coal in such a system from one pile to another, an almost unlimited capacity may be secured.

In the accompanying table, which was published in a report of the American Engineering Council, are shown the storage capacities with this system for cranes of different radii and for the two conditions: (1) where the crane tracks are covered, and (2) where the crane tracks are left uncovered. The railroad tracks are assumed to be 27 ft. center to center and the coal to weigh 50 lb. per cu. ft.

Where exceedingly large quantities of coal are to be stored and where rapid handling is necessary, the bridge crane is applicable. This system usually stores coal in the form of rectangular piles on the area swept by the bridge.

CAPACITIES OF CIRCULAR CRANE STORAGE

Radius of Crane (Ft.)	Crane Tracks Covered* (Feet)						
	10	15	20	25	30	35	40
35			7,000				
40			9,000	12,400			
45			11,500	16,000			
50			15,000	19,500	25,300		
55			17,600	24,000	29,200		
60			22,700	28,500	35,400	43,100	
65			25,600	32,800	39,100	46,900	
70			30,500	39,100	46,300	54,300	
75			32,600	44,300	55,600	63,800	
80			39,440	49,700	60,800	69,600	83,200
85			43,600	56,100	68,300	82,300	94,400
90		34,500	46,300	58,100	70,100	84,250	96,200
95		39,130	53,220	66,540	78,800	92,300	106,200
100		43,500	57,700	74,000	89,300	103,900	123,000
110		53,500	71,300	80,000	107,700	123,800	142,300
	Crane Tracks Uncovered* (Feet)						
35			6,050				
40			6,850	8,875			
45			9,280	11,720			
50			11,200	14,000	17,600		
55			13,500	17,100	21,000		
60			15,900	20,400	25,100	29,600	
65			19,400	23,700	29,100	34,500	
70			22,300	29,600	34,200	39,300	
75			25,300	30,800	39,500	45,800	
80			30,100	37,600	45,200	53,600	61,500
85			34,400	41,900	50,700	60,500	71,100
90		31,200	41,500	52,100	60,800	70,800	80,600
95		32,900	43,860	54,500	63,000	72,100	82,500
100		36,200	47,000	60,000	69,000	79,100	90,600
110		45,600	60,100	74,000	85,000	94,800	106,500

* In some systems, when the pile is full, the circular track is completely covered by the coal

Where a system of great flexibility is desired, the drag scraper system has much to offer. It gives hourly capacities ranging from 60 to 600 t. per hr. based on an average haul of 100 ft. The height to which coal can be stored with the drag has not been determined but in some instances coal has been stored 35 to 40 ft. deep.

In the use of any of these systems, the first problem

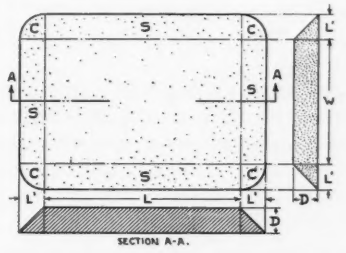


FIG. 8. DIAGRAM FOR USE IN FIGURING CAPACITY OF A RECTANGULAR COAL PILE

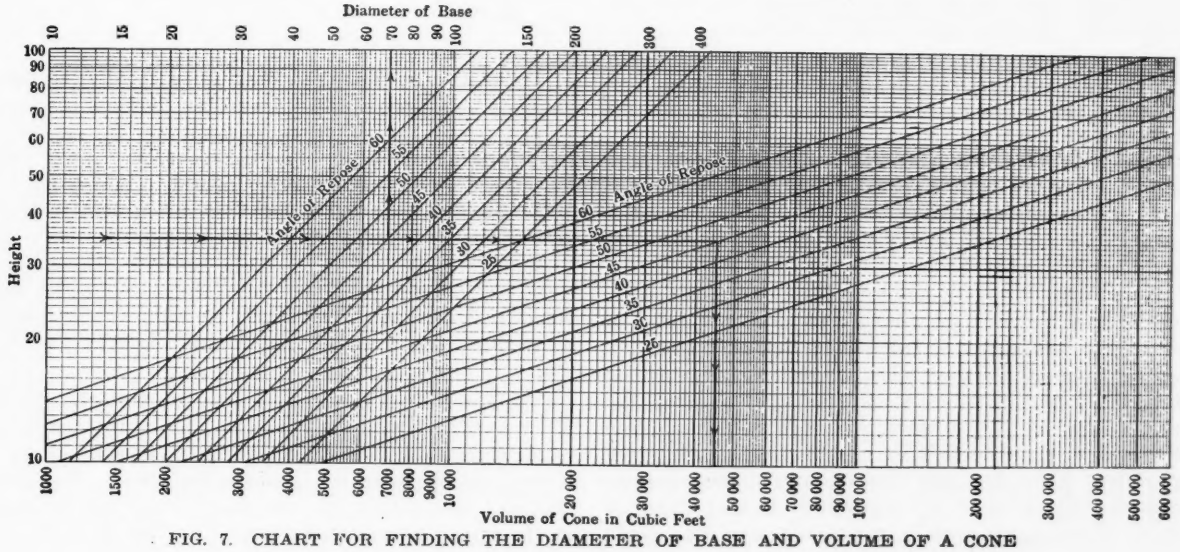


FIG. 7. CHART FOR FINDING THE DIAMETER OF BASE AND VOLUME OF A CONE

is the determination of the size of pile required for a specified volume or tonnage of coal. For this purpose, the accompanying chart, Fig. 7, is useful. This chart gives the volume and base diameter of a cone of any known height and angle of side. In the diagram, Fig. 8, the four corner sections of the rectangular pile are the four corners of a cone. The combined volume of these four sections may be read from Fig. 7 and labeled V_1. The volume of the central part of the pile will be $L \times W \times D$ where D is the depth. Label this volume V_2. The volume of the four side sections S will be $(L + W) \times D \times L^1 = V_3$. The total volume of the pile in cubic feet then is $V_1 + V_2 + V_3$. Dividing this result by 40, the number of cubic feet per ton will give the number of tons of coal in the pile.

In determining the space required for coal storage, the angle of repose for bituminous is usually assumed to be 40 deg. while for anthracite it is 27 deg.

Costs of Maintaining Coal in Storage

FACTORS AFFECTING COSTS. OPERATING COST. INVESTMENT INSURANCES. TYPICAL COSTS FOR VARIOUS TYPE SYSTEMS

FIGURES ON THE cost of coal storage at various plants indicate a wide variation when unit costs are considered. In an investigation made by the United States Coal Commission some years ago in which hundreds of firms storing coal for industrial plant use were interviewed and their records examined, it was almost impossible to obtain any general figures which would be of value.

FACTORS INVOLVED IN THE COST OF STORING COAL

Each power plant is affected by individual local conditions any of which alone, or all combined, may cause the total costs of storage to vary between wide limits. In determining the cost of storage for any plant, the following factors must be considered: (1) Cost of handling. (2) Interest on capital invested in equipment and land. (3) Taxes. (4) Interest and insurance on coal.

The cost of handling depends largely upon the character of the equipment used. In its determination must be considered the cost of power, cost of maintenance and repair, depreciation. Item number two varies greatly according to the character of the equipment provided and the location of the storage site. Item three needs no comment; it also varies widely, depending upon location. The interest and insurance on the coal is dependent upon the amount stored and the length of time it is kept in storage, as well as upon how well the coal is protected against spontaneous combustion.

Several years ago, the American Engineering Council conducted an extensive investigation into the storage of coal. In the course of this investigation, it was brought out that for industrial consumers in general, there should be a seasonal storage of coal equivalent to 9 per cent of the annual consumption. This is in addition to the reserve stocks generally carried as insurance against cessations of coal deliveries. The number of days' supply in stock ranged in general from 10 to 30. Taking 20 as an average and a working year of 300 days, the average per cent of annual consumption carried in stock is approximately 7, from which the conclusion may be drawn that all consumers of coal should store at least 9 per cent of their annual consumption during the period from April to September of each year in addition to the 7 per cent generally carried in stock for insurance purposes. For this reason, the maximum storage capacity required would be 16 per cent of the annual consumption. These figures must be regarded as average. Many plants will require more than this amount, others less.

For a small plant storing not over 1000 tons and consuming about 5000 t. annually, the figures for the investment were determined by the Engineering Council Committee on the following basis:

TYPICAL FIGURES FOR A SMALL PLANT STORAGE

Assuming that a plant uses two carloads a week, 5200 t. a year, on the 9 per cent basis, this plant would require a seasonal storage capacity of 0.9×5200, or 468 t., and a reserve capacity of 0.7×5200, or 364 t., a total of 832 t.

Assuming that an area of approximately 5000 sq. ft. will be necessary, the cost for an 832-t. storage plant would be as follows:

Land, 5000 sq. ft.	$ 670.00
Railway trestle	1100.00
Preparing the ground, grading, packing, building low bulkheads, etc.	300.00
Handling equipment (a variable item varying greatly in plants investigated) say	500.00
Total	$2570.00
Investment per ton stored	3.08

Reports from industrial firms investigated by the committee on plants between 500 to 2000 t. gave investments ranging from $1.00 to $9.00 per ton.

OPERATING COSTS

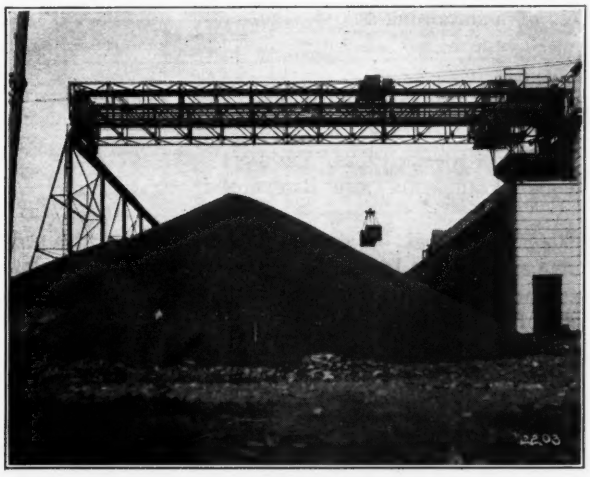
From data submitted in these same reports, operating costs were found to vary from 20 to 60 cents per ton, an average of, say, 40 cents. By allowing 12 per cent for fixed charges, the investment expense is 37 cents per ton on the basis of 832 t. being placed in and removed from storage annually. Interest on investment in coal at $5.00 per ton computed at 6 per cent per annum and carried for 6 months is 15 cents per ton. Insurance, taxes and deterioration may be disregarded in this instance. Adding the above items, the total carrying and operating expense on 852 t. is found to be 92 cents per ton.

At 92 cents per ton, the total annual cost of storing 892 tons of coal would be $765.44. This figure, however, is not necessarily final since a variation in price of coal throughout the year may make a difference. Suppose that coal is sold from 50 cents to $1.00 per ton cheaper in the spring to encourage buying at that time of the

year. At 75 cents per ton, the saving effected in buying the 832 t. at that time would be $624.00. Subtracting this from $765.44 gives $141.44, or 17 cents per ton stored. If the net cost is distributed over the entire 5200 t. annual consumption, the cost is only 2.7 cents per ton.

These figures are given here primarily for the purpose of indicating the method by which coal storage costs may be determined. For large plants where from 50,000 to 200,000 t. are stored, the costs might be much lower. In smaller plants, it may run much higher.

Considering interest and maintenance of the mechanical equipment, interest on the coal cost, including freight and deterioration and shrinkage of coal, the costs of storing coal for various types of plants ranges from 50 to 75 cents per ton for large storage (50,000 t. or more), to from $1.00 to $1.50 per ton for small storage of a few hundred to a thousand tons. These costs, which are abstracted from a report of the U. S. Coal Commission, are on the quantity of coal actually stored but spread over the total tonnage used in a year and figured as cost per ton for all coal used, the figures are much less. This is the fair basis for calculating the cost of storage.



STORING COAL BY MEANS OF A BRIDGE CRANE AND GRAB BUCKET

The difficulties involved in securing even rough general figures on the cost of storing coal may be appreciated from the following case. Two neighboring plants may each store 3000 tons. One plant, with hand-fired boilers, has a trestle bunker adjacent to the boiler house where this tonnage can be dumped at an additional labor cost of, say, 5 cents a ton. The bunker is used for the ordinary car to boiler operation and the handling of this additional tonnage does not add to the interest or maintenance charges on the equipment. When reclaiming from this storage, the fireman wheels the coal as he ordinarily would so that reclaiming represents a little extra labor for him but involves no additional expense. The only items which can be properly charged to storage here are labor costs of trimming, estimated at 5 cents; interest on investment (coal and freight), estimated at 25 cents; and deterioration and shrinkage, estimated at 25 cents; making a total of 55 cents a ton.

At the adjoining plant are installed overhead bunkers with capacity for a week, receiving the coal by elevator from a track hopper. Here the existing equipment cannot be utilized for storage; additional mechanical equipment must be installed or the coal handled by hand. In this case, the charge may run from 5 to 10 cents per ton with mechanical equipment in and out of storage to 50 cents or $1.00 per ton with hand labor.

Typical Costs

To indicate how storage costs may vary, cost data on a number of plants using various types of handling equipment are given in the accompanying table. These are random cases, selected without regard for their location. These figures were obtained from the report of the American Engineering Council already referred to.

Public Utility Plants

Plant No.	Storage capacity	Method of handling	Inv. per ton	Operating Expense in and out per ton
1	250,000	Gantry and loco. cranes...	$5.82	$0.57
2	99,500	Traveling bridge	5.83	0.25
3	65,000	Loco. crane, belt conveyor	2.30	0.16
4	30,000	Tower and loco. crane....	6.88	0.12
5	25,000	Loco. crane	2.00	0.50
		Industrial Plants		
1	95,000	Gantry crane	$1.13	$0.06
2	20,000	Trestle, loco. crane, scraper	.75	0.40
3	12,000	Loco. crane	1.25	0.15
4	12,000	Loco. crane	2.00	0.16
5	10,000	Gantry crane	4.00	0.10
6	10,000	Steam shovel	.80	0.85
7	10,000	Elevator, dump cars.....	2.50	0.25
8	7,000	Track hopper, elevating and dist. belts.....	2.85	0.45
9	6,000	Loco. crane	2.83	0.06
10	5,000	Monorail and clamshell...	4.00	0.04

It is evident that there is little consistency between these figures. Investment costs run from 75 cents to $6.88 while operating expenses vary between 4 cents and 85 cents.

For a small to moderate sized plant, the trestle and crane system is used extensively. The crawler type locomotive crane has advantages for the small plant because of its adaptability for miscellaneous service. A crane of this type equipped with a 40-hp. gasoline engine and with a 35-ft. boom can be bought for approximately $10,000.

Using this type of crane, the cost of a 7500-t. storage plant would be about as follows:

Land	$ 3,000
R.R. switch and miscellaneous	4,000
Crawler type crane	10,500
Total	17,500
Investment per ton capacity	$2.33

With operating costs at 20 cents per ton, an average figure, and allowing 12 per cent for fixed charges the investment expense is 28 cents per ton on the basis of 7500 t. being placed in and removed from storage annually. Taking account of the interest on investment the total carrying and operating expense on the 7500 ton basis becomes 65 cents per ton. If the expense is distributed over the entire annual consumption of 47,000 t. (determined on the basis of 16 per cent of annual consumption) the cost per ton will be 10.3 cents.

At another plant, a typical plant using the drag scraper system of storage, a storage area of 50 × 350 ft. in which a maximum of 13,000 t. could be stored, the cost of equipment was 92 cents per ton, and the total operating cost including insurance and investment charges, was 25.6 cents per ton.

This case is of interest because it represents a special case where although the capacity of the storage was only 13,000 t., the actual coal moved into and out of storage was 50,000 t. If the surplus quantity needed at this plant were just equal to the storage capacity (13,000 t.), the cost of handling would be different from the 25.6 cents given above. Where the larger tonnage is actually handled, it is evident that the storage plant serves a more extended purpose than simply storing 13,000 t. of coal, so that it would not be correct to charge the whole equipment against seasonal storage. If only the 13,000 t. of coal had been handled, the items of power, labor, maintenance and depreciation would be less than the figures given.

Insurance

In estimating coal storage costs, insurance and taxes have an important bearing on the total cost, particularly in the case of large plants where large stocks are maintained in storage. Insurance costs vary from $1.25 to $3.00 per $100, where the insurance covers loss due to spontaneous combustion to from 40 to 50 cents per $100, where the insurance does not cover loss against fires arising within the coal.

In any consideration of costs of coal storage, the fundamental purpose of coal storage must not be lost track of; the value of a coal storage plant in preventing an enforced shut-down of a large factory even for a few days is often great enough to outweigh years of cost of maintaining the storage.

Experiences with Coal Storage Practice

Methods Used by Various Companies, Sizes of Storage Piles, Amounts Carried, Troubles Due to Spontaneous Combustion and Remedies

IN NO BRANCH of the power plant industry is the storage of coal more important than in the central station field. Because of the absolute necessity of maintaining a continuous output under all conditions, an adequate supply of coal must be kept on hand to maintain the plant in operation even during a long interruption of the coal supply. Some form of storage, therefore, is an essential part of all central stations. The amounts carried varies between 10,000 and 300,000 t. Most of the larger plants carry at least 100,000 t.

EQUIPMENT FOR RECEIVING, STORING AND RECLAIMING COAL AT SAGINAW RIVER STATION OF THE CONSUMERS POWER CO.

Underwater Storage at Philo Station

While it is almost universal practice to use open storage, several of the central stations are using underwater storage. A system of this kind is in use at the Philo Station of the American Gas and Electric Co. At this plant, a portion of an old canal between existing locks in the river has been widened and deepened for a submerged coal storage which will hold approximately 300,000 t. of coal. Water may be admitted or drained from this storage by control valves at the locks. A dry storage of 100,000 t. capacity has been developed along side of the submerged storage.

Three parallel railroad tracks serve this coal storage, one on either side of the dry storage and one over the center of the submerged storage. Coal is reclaimed from the submerged storage and is dumped into duplicate crane track hoppers by means of a bridge crane. Reclaimed coal is passed through a crusher, after which, by means of belt conveyors, it may be deposited in dry storage.

Novel System in Use at Philadelphia Electric Co.

At the Philadelphia Electric Co., in order to eliminate spontaneous combustion without the disadvantage of submerged storage, a unique but effective method of storing has been devised. This company maintains a large storage, having over 225,000 t. of bituminous on hand at times. Although this coal has been in storage over periods of 2 yr. or more, no trouble has been experienced from deterioration.

The ground is prepared by covering it with ash or dry earth and rolling it hard. Over this the base of the coal pile is started by spreading a layer of coal, approximately two feet deep, over a width of from 90 to 100 ft. and 1000 or even 2000 ft. in length. This is handled by a locomotive crane. A caterpiller tractor weighing approximately two tons then grades this first layer with a drag and after the coal has been leveled a roller is drawn over the pile, thus packing the coal until it weighs approximately 65 lb. per cu. ft. The second layer is then started in precisely the same manner and after it is packed, the third layer, and so on until the top of the pile is only as wide as the tractor.

During the time that this pile is being built, a certain amount of loose coal runs down the sides of the pile and if left there might cause fires. To eliminate this, the operator on the crane trims the sides of the

pile at the ground level the width of his bucket after the pile has been completed and in this manner gathers up the loose material and places it on the very top, thus forming the crown of the pile. The pile has now been packed thoroughly from top to bottom. The interesting feature of this is that coal which would weigh 45 and 50 lb. per cu. ft. if piled normally now weighs 65 lb. per cu. ft. The surface of these piles is so closely packed that they readily shed water and in all probability the circulation of air is entirely eliminated.

Temperatures taken at least every 6 weeks indicate clearly that there is a considerable lag of temperature within the coal pile compared with the external air, showing that there is no free circulation of air in the pile. The coal piles average from 25 to 30 ft. in height and from 90 to 100 ft. in width at the base. It has been found necessary to crush the coal to insure success with this method.

In any coal storage, the complete prevention of an additional oxygen supply beyond that absorbed by the coal before entering the storage will insure against any appreciable rise of temperature. The underwater storage is perhaps the most effective of any of the various systems in use in accomplishing this, but because of the expense involved in maintaining underwater storage, a system such as the one used by the Philadelphia Electric Co. has much to recommend it.

For most plants, however, the simple open coal pile, carefully inspected at frequent intervals seems to give no particular difficulties. A typical system of this kind is shown in the accompanying photograph which is that used at the Saginaw River plant of the Consumers Power Co. Coal is brought to the plant by railway and dumped into track hoppers. Two feeder belts dump the coal on an inclined belt conveyor which carries it to the crusher house. Coal passes either through or around the crusher house to the boiler house or is delivered to an inclined belt conveyor which delivers it to the drag line shown in illustration. The drag line delivers it to the 75,000-t. storage pile where it is distributed by a drag scraper system with gasoline propelled tail car.

Experiences of New England Companies

Several years ago, the New England Geographic Division made a study of seasonal storage of coal among member companies in its division, covering methods used in receiving coal, difficulties encountered and methods used in storing and reclaiming coal, tendencies of coal to fire and means used to extinguish fires. The results of this study are given in the accompanying table. At the plants considered in this study, the storage capacity varied between 10,000 and 80,000 t. average and was stored in open piles.

Among the chief causes of trouble reported due to spontaneous combustion, was the presence of foreign matter, wood, straw, etc., in the coal. In two cases, the trouble was attributed to the fact that the coal was stored on grassy land or containing other organic matter, while four cases cite the mixing of various sizes or kinds of coal. This factor is one of great importance; in fact, the question of coal types has little significance compared to the importance of uniformity of size and accessibility of air currents. The absence of air currents is the prime requisite and this, as is evident, is controlled by the physical characteristics of the coal and the manner in which it is piled rather than its chemical composition.

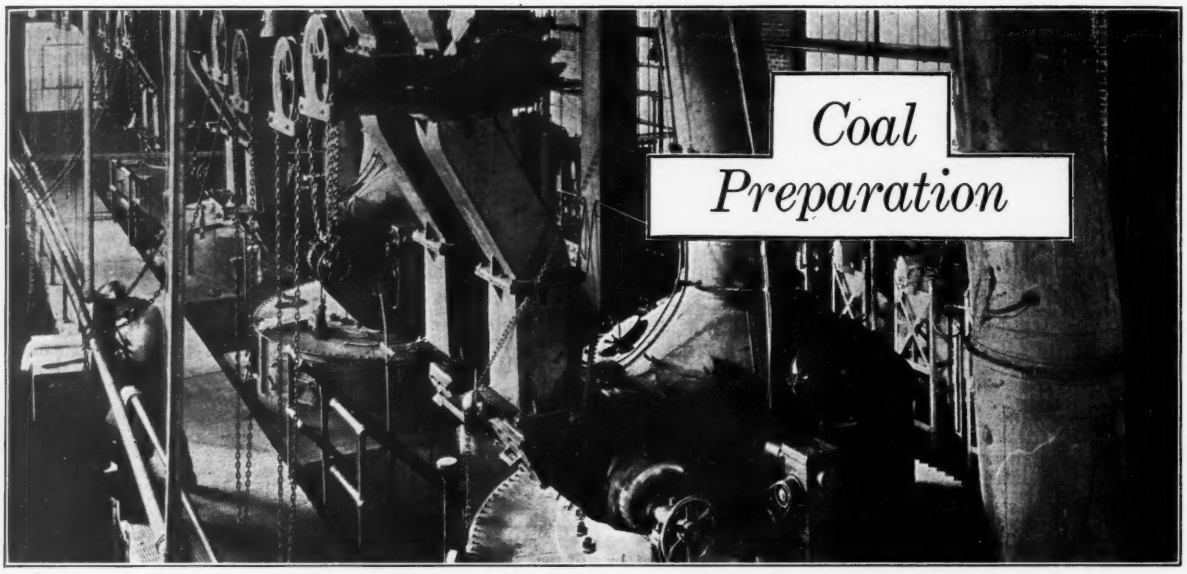
Another cause of spontaneous combustion, as will be noted, is high piling of the coal. Theoretically, the height of piles is limited only by the increased tendency towards segregation of sizes with increase in height. It has been found that a storage mass of lump coal adjacent to a pile of slack will heat at the border line. Such division lines apparently form channels for a limited admission of air and this must be avoided. There must be free circulation or no circulation of air.

The remedies or preventatives employed in each of the cases cited were usually dictated by the cause of the trouble itself. Moving of the heated coal is the obvious remedy where heating has started and seems to have been found effective. Once heating has started, this is about the only practical remedy because the oxidation of coal is much more rapid at high temperatures than it is at low temperatures, and usually any method other than the actual removal of the coal is too slow to prevent reaching the ignition temperature.

Information on the success of storage of coal at industrial power plants is meager. The amount of coal stored at industrial plants is usually considerably smaller than that stored at central stations, hence chances for spontaneous combustion are lessened.

RESUME OF COAL STORAGE AND HANDLING PRACTICE IN NEW ENGLAND

STATION.	OPERATING COMPANY	MAXIMUM STORAGE.	AVERAGE STORAGE.	APPROXIMATE GROUND DIMENSIONS.	APPROXIMATE HEIGHT.	METHOD OF RECEIVING COAL.	METHOD OF UNLOADING COAL.	METHOD OF STORING COAL.	METHOD OF HANDLING COAL.	METHOD OF RECLAIMING COAL.	SPONTANEOUS COMBUSTION. CAUSE.	SPONTANEOUS COMBUSTION. PREVENTION.	REMARKS.
E. BRIDGEWATER	BROCKTON EDISON CO.		10-15,000 Tons.	75'×30'	15' to 20'	Rail	Trestle & Loco Crane.	Piles	Crane to Crusher to Bunkers.	Loco. Crane.	Storage on grassy land. Use of wood for bin walls. Mixing of various kinds of coal.	Use of good grades of coal. Small storage piles.	Only surplus coal put in Storage.
DEVON.	CONNECTICUT LIGHT & POWER CO.	50,000 Tons.	43,000 "		12'	Rail.	Trestle & Crane	Compacted Piles.			High loosely packed piles.	Spread & spiked piles of medium height. Moving of heated coal.	
	DERBY GAS & ELECTRIC CO.	30,000 "	15,000 "		High	Water.	Crane, also Tower	Piles.	Motor Trucks from Storage Yard to Station Hoppers.		High piles. Mixing of various kinds of coal.	Storage of each kind of coal separately.	Storage yard is approximately 2 miles from the Station
MONTVILLE.	E. CONNECTICUT POWER CO.		20,000 "	90'×200'	15' to 20'	Water, also Rail Facilities.	Tower. Loco. Crane. Drag Scraper.	Piles			Wood, straw & other inflammable material becoming mixed with the coal.	Low level piles. Moving of heated coal. Keeping coal free of inflammable material.	
	HARTFORD ELECTRIC LIGHT CO.	60,000 "				Water & Rail.	Loco. & Gantry Cranes.	Piles		Loco. & Gantry Cranes	Mixing of various kinds of coal. Storage on soils containing organic matter.	Use coal before certain time elapses. Immediate use in Boiler House. Moving of heated coal. Storage of each kind of coal separately.	Cooling water pipes placed in piles. Not expense incurred, due to moving required, over balanced that due to coal set by fire.
	HAVERHILL ELECTRIC CO.		12-14,000 "		14' to 16'	Water.	Loco Cranes.	Piles.		Loco. Cranes	Very little trouble.	Moving of heated coal.	
	LOWELL ELECTRIC LIGHT CORP.	50,000 "	12,000 "			Rail	Trestle. Loco. & Electric Cranes.	Piles	Track Hopper to Crusher to Bunkers.	Loco. & Electric Cranes	Very little trouble.	Moving of heated coal	Only surplus coal put in Storage.
	SALEM ELECTRIC LIGHTING CO.	18,000 "		200'-300' Long.		Water	Loco. Cranes.	Piles.		Loco. Cranes	Very little trouble.	Moving of heated coal.	Temp. pipes used, 25' centres along crest of pile. Readings are taken systematically.
WEBSTER.	WEBSTER & SOUTHBRIDGE GAS & ELECTRIC CO.				16' to 18'	Rail, also Water Facilities		Compacted Piles.	Cars to Bunkers.		Foreign matter in coal. Mixing of coal of varying quality & degrees of coarseness	Removal for use in Boiler Rm. Raking of piles by means of Trucks.	Only surplus coal put in Storage.
WEBSTER STA.	WORCESTER ELECTRIC LIGHT CO.	40,000 "	25,000 "		12' to 15'	Rail.		Piles	Cars to Crusher to Bunkers.	Cranes & Cars		Keeping coal free of inflammable material. Moving of heated coal.	Only surplus coal put in Storage. Temp. sentinels used, 15' centres.
L. STREET.	EDISON ELECTRIC ILL CO. OF BOSTON.	150,000 "	50-80000 "		30'	Water.	Tower & Bridge Hoists.	Piles.	Vessels to Bunkers	Belt Conveyors.		Moving of heated coal. Immediate use in Boiler Rm.	Only surplus coal put in Storage.



Preparation of Coal for Storage and Burning

SIZING AND CRUSHING COAL MAKE IT EASIER TO HANDLE AND BETTER TO BURN

AS COAL USUALLY comes to the power plant, it is seldom in just the proper condition to put into storage, deliver to the power house bunkers or to the pulverizing mills. For this reason, several stages of preparation are generally provided in the power plant to condition the coal that it may best serve as fuel.

In order that a plant may be in position to buy coal of any size which is available on the market, coal crushers have become customary equipment in plants of medium to large size and to protect these from foreign material which may come with the coal, track hoppers are usually provided with gratings of a size which will prevent anything larger than the crusher can accommodate from passing through into the hopper. This not only keeps the oversize lumps of coal from passing direct to the crushers but also prevents such foreign material as mine props from interfering with the operation of the coal preparation equipment. The large sizes of coal, of course, are broken up manually so that they will then enter the hopper.

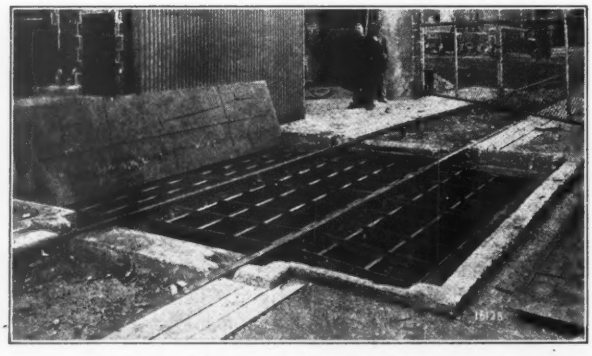


FIG. 1. TRACK HOPPER GRATINGS PREVENT OVERSIZE LUMPS FROM ENTERING COAL HANDLING SYSTEM

COAL CRUSHERS

Although several types of coal crushers will operate when taking their feed directly from the track hopper, it is usually advisable to install some sort of feeding device, such as an apron conveyor or plate feeder so as to prevent the crusher from dragging too much coal into the rollers and thus become stalled. In many plants, also, it is considered essential to provide a magnetic means for removing any tramp iron which may come along with the coal and thus prevent it from damaging the crusher.

Two forms of magnetic separators are available, one of these which has proved popular in power plants is the pulley type which consists of a magnetized pulley at the discharge end of a belt conveyor which attracts the iron to the pulley as it passes over with the coal and drags it back until the belt forces the iron off into a chute, thus separating it from the coal which has been discharged to another chute leading to the crusher. The other type of magnetic separator consists essentially of an electro magnet which is located a little way out of the path of the falling coal and attracts any iron which may come over with the coal to one side, holding it against the magnet until it is removed by the operator.

For power plant purposes, either the single roll or the two roll type of coal crusher may be used. The former works against an inclined jaw plate which is either backed by a spring or weighted and hinged. There are, of course, several types of rollers, some provided with slugging teeth, others with swing ham-

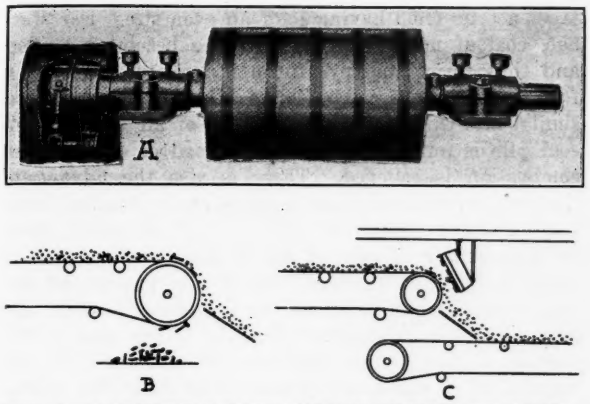


FIG. 2. MAGNETIC PULLEY AND PRINCIPLE OF OPERATION, ALSO DIAGRAM OF SEPARATOR MAGNET PRINCIPLE

mers and still others with ring hammers. Any of these will reduce lump or run-of-mine bituminous coal to stoker size by passing it once through the crusher.

As previously stated, they can be operated directly under the track hopper, but where they discharge to a belt conveyor or elevator, a feeder is a necessity. Two roll crushers have a wider mouth or opening than the single roll crushers and if set directly under the track hopper they are likely to drag more coal than they can crush. To avoid this choking, a feeder is generally found necessary. Coal passing through a two-roll crusher can be made finer than that passed through a single-roll crusher and is thus more suitable to be sent to pulverizers. In nearly all crushers there is a release device of some kind, either a hinged jaw plate or a spring mounted roll to yield in case some foreign substance enters with the coal.

In Fig. 5 is shown what is known as the Bradford type of breaker which consists of a revolving screen with internal shelves that lift the particles of coal that have not passed through the screen and drop them upon each other until they are broken so fine that they pass through the screen. Foreign matter such as tramp iron and mine rock that will not break up with the coal travels the length of the breaker and is discharged at the end opposite the intake. Neither magnetic separators nor grizzlies are needed with this type of breaker.

Use of Grizzlies

When large quantities of unsized coal come to a plant, it is not necessary to pass all of this through

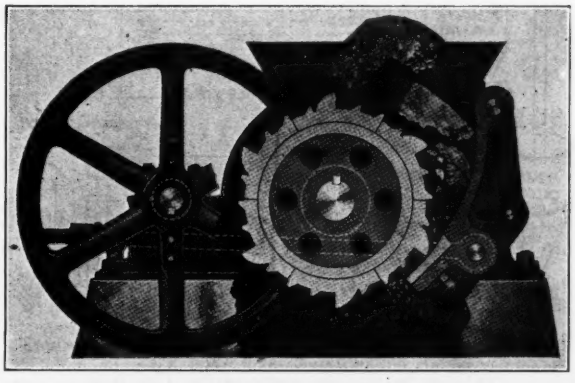


FIG. 3. SINGLE ROLL TYPE CRUSHER

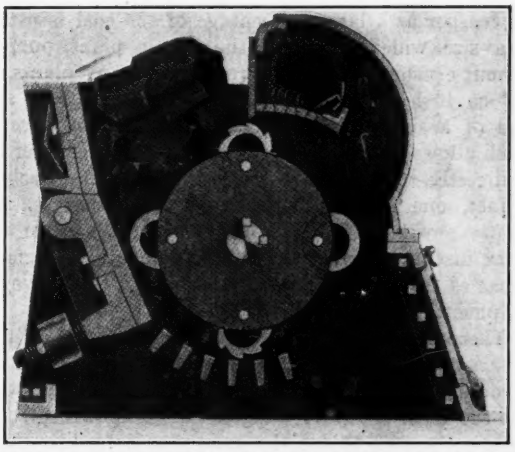


FIG. 4. COAL CRUSHER OF THE ROLLING RING TYPE

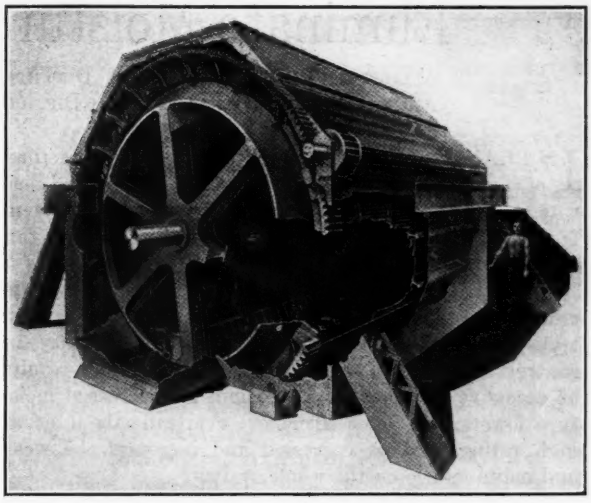


FIG. 5. BRADFORD BREAKER CRUSHES BY DROPPING LUMPS UPON EACH OTHER

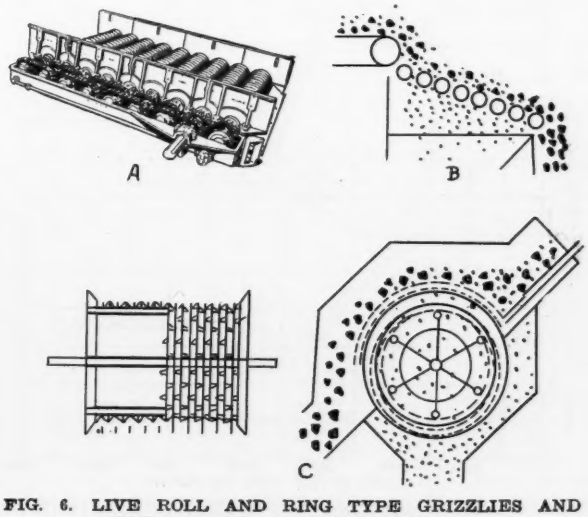


FIG. 6. LIVE ROLL AND RING TYPE GRIZZLIES AND THEIR PRINCIPLES OF OPERATION

the crusher as a large percentage of the coal is usually of a size which will suit the power plant purposes without crushing. For this reason, in many plants, the coal as it leaves the track hopper is run over some kind of a sizing device such as a grizzly or a screen, which allows the finer coal to slide past the crusher and go directly to the conveying equipment. A grizzly is, in fact, one form of traveling screen; that is, it is usually power driven and coal which falls upon it is either discharged over the end as lumps to be crushed or passes through the grating as fines to the conveying equipment.

There are many types of grizzlies, some consisting of bars attached at either end to endless chains, others as corrugated rollers or overlapping disks, while others take the form of squirrel cages. In the power plant, it is quite common to use the grizzly as a feeding device for the crusher.

In the storage and burning of coal, several advantages accrue from having it of an even size. For storage, coal of mixed sizes is likely to become stratified and thus form chimneys through the coal pile which foster spontaneous combustion. Where the coal is of a similar size throughout, the passage of air through the coal pile is uniform and the likelihood of spontaneous combustion is relieved. There is also the advantage that coal of uniform size is more easily handled with the conveying equipment than is coal of mixed sizes. In the burning of coal of mixed sizes, the fuel bed is likely to become stratified, due to the passage of the coal from the bunker chutes to the stoker hopper, the fines settling to the center and the larger coal to the outside of the chutes and hoppers, thus making an uneven bed of coal on the grate and in the stoker retort. Such a fuel bed is difficult to handle as certain areas will burn out much more rapidly than other areas and it is thus difficult to maintain an even fuel bed. This situation is relieved by having the coal of uniform size.

Eliminate Moisture in Pulverized Coal

ALLOWABLE MOISTURE CONTENT DEPENDS UPON TYPE OF COAL; 1.5 PER CENT IN ANTHRACITE MAY CAUSE AS MUCH DIFFICULTY AS 25 PER CENT IN LOW GRADE LIGNITE

IN PLANTS using the central, bin or indirect method of firing pulverized coal, moisture in the coal has a tendency to cause trouble in all parts of the system from the mill feeders through to the indirect draft fan or stack.

Condensation and corrosion on the sides of conveyors and bunkers, bridging or arching over the feeder screws, transport troubles, uneven feeding with difficulty in controlling combustion and flame length are all results of excessive moisture. In addition, the increased moisture lowers the boiler efficiency, overloads the fans at high ratings, favors corrosion and increases the wear and maintenance on the whole system.

Moisture is present in two forms as inherent moisture due to the character and composition of the coal and surface moisture which can be removed without changing the character or composition of the coal. This surface moisture is the index of the workability of the coal in a pulverizer although the general character of the coal must be considered as well. Anthracite with 1.5 per cent moisture may cause as much difficulty as Texas lignite with 25 per cent. It is generally believed that the ratio of surface to inherent moisture is the determining factor.

MOISTURE DECREASES MILL CAPACITY

Performance of a pulverizer using Illinois and Kentucky coal with varying moisture contents is shown by the curves in Fig. 1. At 4000 lb. per hr. a moisture content increase from 8 to 12 per cent means a power increase of about 13 per cent, or with a constant power increase a reduction in mill capacity from 4000 to 3150 lb. per hr.

The importance of coal drying is self-evident and

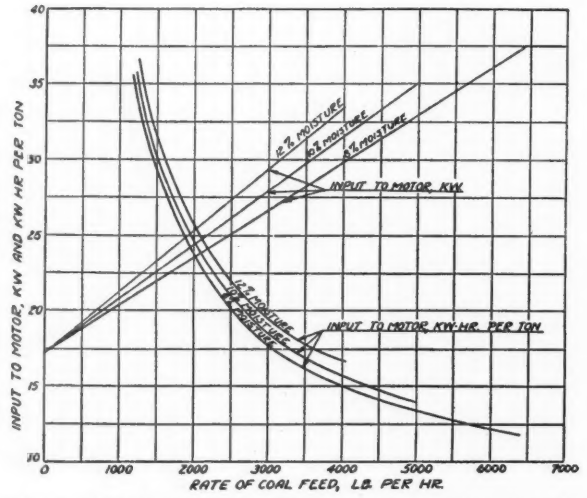


FIG. 1. CURVE SHOWING THE EFFECT OF MOISTURE ON THE CAPACITY AND POWER INPUT OF A 2½-T. MILL

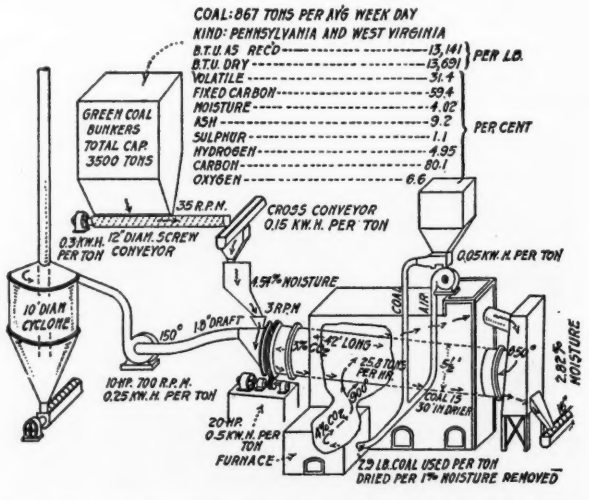


FIG. 2. ARRANGEMENT OF EQUIPMENT AND POWER CONSUMPTION OF A DIRECT FIRED DRYER INSTALLATION

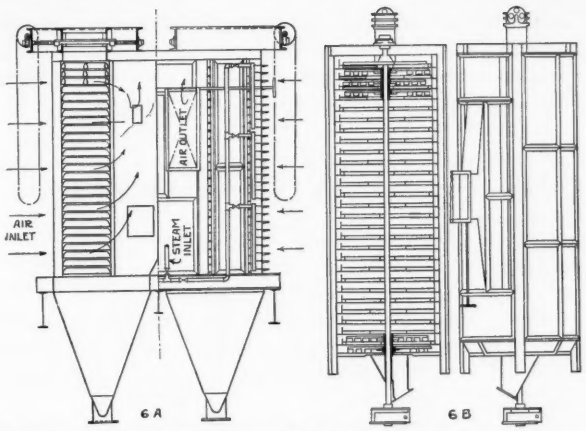


FIG. 3. TWO TYPES OF STEAM COAL DRYER; STATIONARY (LEFT) AND ROTARY (RIGHT)

this drying is usually accomplished in power plant service by the use of hot gases, flue gases, steam or warm air, using any one or a combination of the following methods:

1. Direct or indirect fired rotary dryers ahead of the pulverizer.

2. Stationary or rotary tower dryers ahead of the pulverizer.

3. Admitting preheated air or gases into the pulverizing system.

Rotary dryers of the type shown in Fig. 2 are usually separately fired with gas, oil or coal. Figure 3 shows two types of steam dryer. In all of these dryers, the general scheme is to have the coal pass downward by gravity counterflow to the hot gases or air, these gases absorbing the moisture as they passed through the rather finely divided particles of coal.

Admitting Warm Air or Gas to Mill Is Effective Method

When the moisture content is low, drying may not be necessary or warm air or flue gas may be admitted to the mill with the coal. The milling will have a drying effect in itself and if preheated air or flue gas is admitted, the coal can be dried to any reasonable figure.

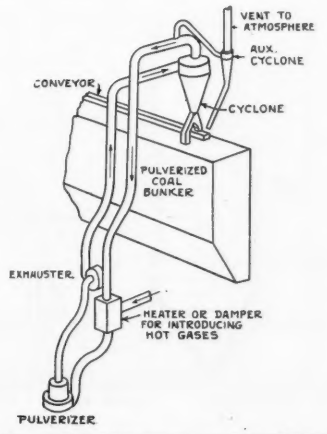


FIG. 4. TYPICAL ARRANGEMENT OF PULVERIZING EQUIPMENT WHOSE AIR IS BLED FROM THE SYSTEM

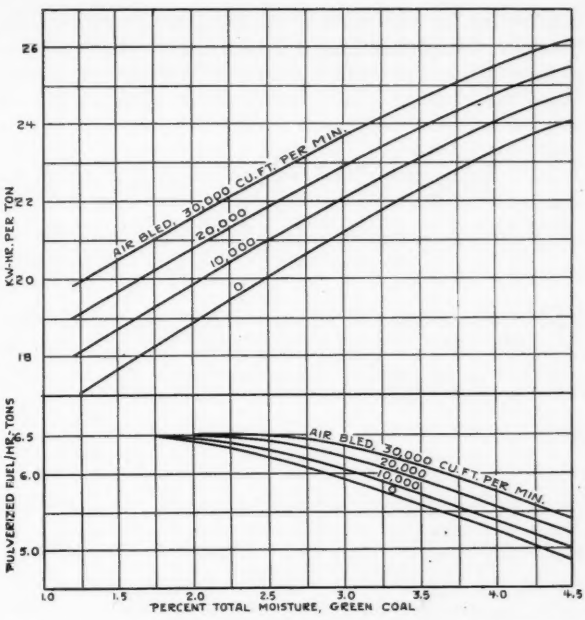


FIG. 5. CURVES SHOWING THE EFFECT OF MOISTURE AND AIR BLEEDING ON MILL PERFORMANCE

Moisture picked up from the coal must, however, be properly vented from the system or sweating and corrosion will take place. This venting is accomplished by bleeding off a certain percentage of the air circulated in the system, a typical installation being shown in Fig. 1. By inserting a heater in the return pipe or introducing hot flue gas into the system, the amount of drying can be increased.

Drying can also be controlled by bleeding various amounts of air, the performance of a pulverizer when operated under these conditions being as shown in Fig. 5. The data from which these curves were drawn was all obtained when grinding the same kind of coal. Bleeding increases the mill capacity and power consumption considerably. The exact amount of air which must be bled in each case depends upon the initial moisture in the coal as well as the relative humidity and temperature of the air. The air bled must be sufficient to carry away enough moisture to reduce the total moisture in the coal to a safe and workable value.

If, instead of room temperature, air, hot air or flue gas is used, the performance of a mill handling a particular coal varies as shown in Fig. 6, the temperatures

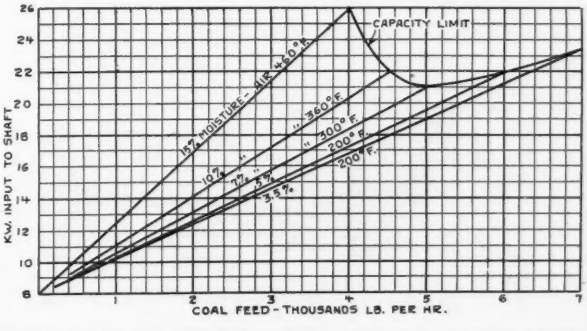


FIG. 6. PERFORMANCE CURVES OF A PULVERIZER UNDER VARIOUS OPERATING CONDITIONS OF MOISTURE AND PRIMARY AIR

indicating the minimum air temperature at which satisfactory mill performance was obtained. Admitting preheated air in this manner is ordinarily preferred in unit fired systems but is not considered as good practice as admitting air at room temperature for central systems because of the increased tendency for the moisture to condense from the hotter saturated air upon striking the cooler surfaces of the piping and bunkers.

Many Pulverizer Designs Give Wide Choice

IMPACT, ROLLER AND BALL MILL DESIGNS MEET ALL CONDITIONS OF SERVICE AND TYPES OF COAL. UNIT AND CENTRAL SYSTEMS MEET ALL POSSIBLE PLANT CONDITIONS

PULVERIZED COAL, as a means of firing boilers, first came into popularity about 1920, although intermittent applications and experiments had been carried on for at least twenty years before this.

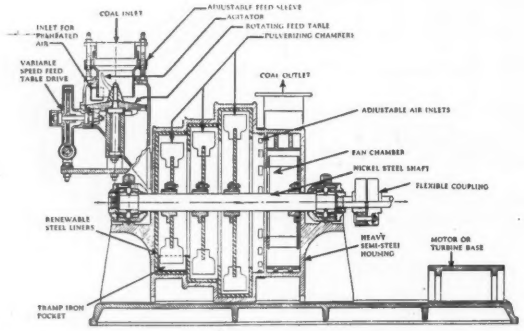


FIG. 1. REPRESENTATIVE TYPE OF IMPACT OR PADDLE MILL

Pulverizers used for preparing or powdering the coal can be grouped into three general classes: First, the impact mill, Fig. 1, in which the coal is broken up into finely divided particles by revolving paddles or hammers, the grinding taking place between the coal and hammers, the coal and metal liners and between the coal particles themselves; second, the roller mill, Fig. 2, in which grinding takes place between balls or rollers running in a race or bullring and third the ball mill, Fig. 3, in which grinding takes place between metal balls or between the balls and shell. Coal and balls are charged in together and the entire shell revolved.

When burning pulverized coal in boiler furnaces, two methods of firing are in general use: first, and the method generally adopted when pulverized coal firing came in vogue about ten years ago, the bin, central or indirect system in which the green coal is first passed through dryers, if necessary, pulverized and then stored in bunkers until used.

These bunkers are usually located above the boilers so that the coal flows by gravity to the feeders, supplying the burners. Formerly it was the practice to have a separate pulverizing house or building, all coal preparation, drying and pulverizing being done at that point and the pulverized coal transported immediately to bunkers over the boiler.

In recent designs, however, this practice has been modified, mills being located in the boiler room proper, a typical systems of this type being shown in Fig. 4. If

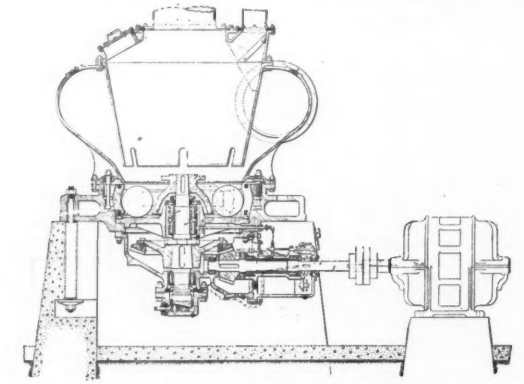


FIG. 2. ROLLER MILL WHERE THE PULVERIZING IS DONE BETWEEN A STATIONARY MEMBER AND ROLLERS OR BALLS

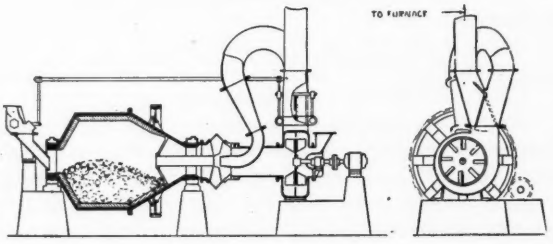


FIG. 3. IN A BALL MILL THE COAL IS PULVERIZED BETWEEN METAL BALLS

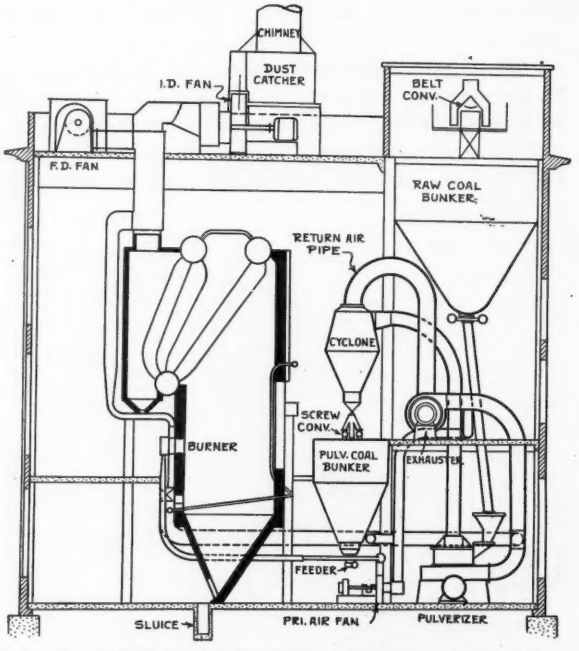


FIG. 4. TYPICAL EQUIPMENT ARRANGEMENT IN A MODERN CENTRAL OR BIN SYSTEM PLANT

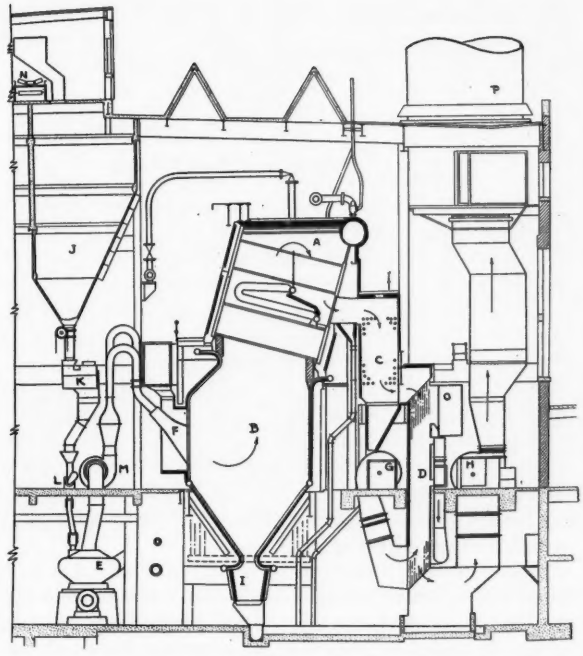


FIG. 5. UNIT MILL OR DIRECT FUEL INSTALLATION IN A RECENTLY COMPLETED STATION

dryers were used, the design would be modified so as to insert a dryer between the green coal bunker and the mill. This arrangement also shows the exhauster on the high pressure side of the mill, a recent advance in power plant design.

The second method of firing is known as the unit or direct system and utilizes individual mills, these mills discharging directly to the boilers without any intermediate bin or feeder arrangement. This system has gained rapidly in favor during recent years, a recent report of the N. E. L. A. estimating at the end of 1928 there would be a total of 140,000 b.hp. of central system boilers and 240,000 b.hp. of unit-fired boilers in industrial plants.

In central stations, conditions are reversed; there being 310,000 b.hp. of the central system against 130,000 b.hp. of the unit system. In both cases, however, the unit system is increasing at a much greater rate. In industrial plants, the gain for the unit system for the past two years has been 160,000 b.hp. against about 35,000 b.hp. for the central system, while in central stations the corresponding figures are 75,000 b.hp. and 50,000 b.hp.

In Figs. 5 and 6, typical unit mill installations are shown. Figure 5 is a cross section of one of the latest central stations and Fig. 6 is a popular layout for industrial return tubular boilers. Preheated air is used in the mill, this air being taken from the air heater at two places, so that by suitable damper control, the temperature to the mill can be maintained at the point which gives the most satisfactory mill performance.

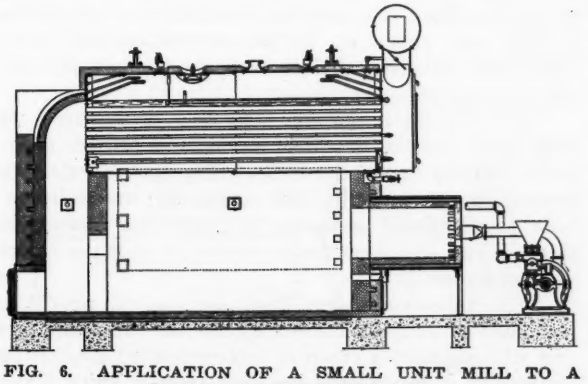


FIG. 6. APPLICATION OF A SMALL UNIT MILL TO A RETURN TUBULAR BOILER

Feeders Control Mill and Burner Performance

Positive Feeder Control and Uniform Mill Feed Are Governing Factors

FEEDERS, for supplying green coal to the mill or pulverized coal to the burners, form an important part of pulverized fuel equipment. For the central system pulverizers, it is desirable to have the feed fairly uniform at all times with the pulverizer working at or near full capacity. With unit mills, an unfailing feed is a necessity as a hold-up in the feed might extinguish the flame while an oversupply might cause the pulverizer to overheat or stop entirely.

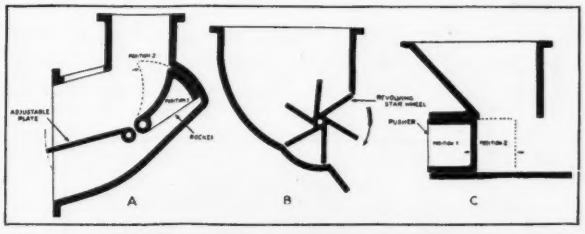


FIG. 1. THREE TYPES OF INTERMITTENT FEEDERS: A, ROCKER; B, REVOLVING POCKET; C, PUSHER

Six types of mill feeders are shown in Figs. 1 and 2, the action of all six being obvious without further explanation. These feeders are in reality part of the pulverizing mill and operate in conjunction with it, regulating the flow of green coal from the green coal bunker to the pulverizer. Sometimes they are mounted directly on the machine while in other cases they are built separately. Particularly in unit-fired plants it is now considered advisable to place the feeder or feeder and exhaust mill on the firing floor where it can be watched and regulated by the firemen, the pulverizer being located on a lower floor where there is more room.

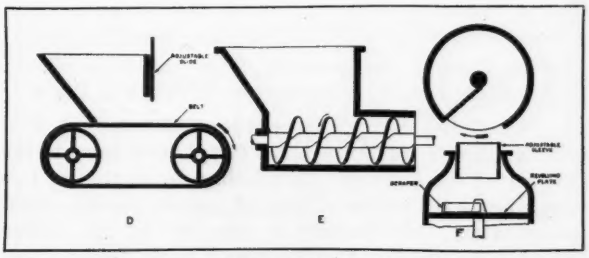


FIG. 2. TYPES OF CONTINUOUS FEEDERS: D, BELT; E, SCREW; F, REVOLVING PLATE

Such an arrangement is shown in Fig. 5 of the previous article.

With unit mills, no auxiliary feeder for the pulverized coal is necessary but for the central system, feeders, to meter and deliver the fuel to the burners, are necessary. These feeders are usually located at the bottom of the fuel bin and receive coal by gravity. As

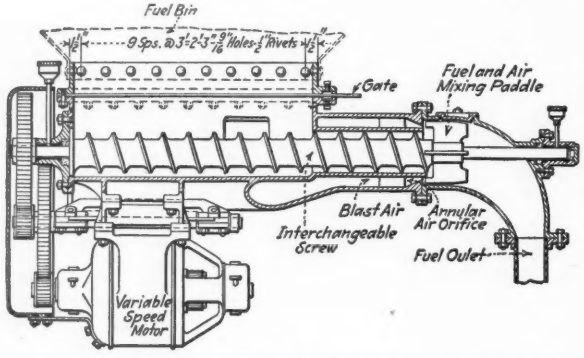


FIG. 3. SCREW TYPE PULVERIZED COAL FEEDER

they control the amount of fuel fed to the burner, it is necessary that they be under instant and accurate control.

One type of screw feeder is shown in Fig. 3. Coal from the fuel bin is forced by the screw out against the mixing paddle where it is picked up by the primary air

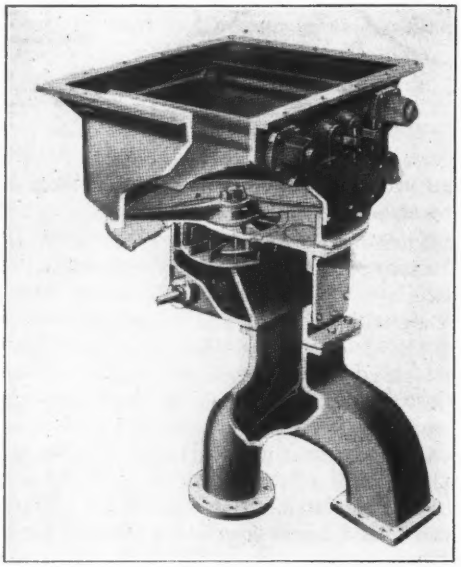


FIG. 4. ANOTHER TYPE OF PULVERIZED COAL FEEDER

flowing through the annular orifice and delivered directly to the burner. Another type is shown in Fig. 4.

This feeder is of a somewhat different type, coal passing downward through the two shutter gates to the bottom of the housing. A rotating distributor at this point keeps the entire volume of coal in motion. Coal passes from this distributor chamber to the fluffer wheel below which in turn delivers it to the feeder wheel immediately below. The feeder wheel rotating carries the coal around to open ports through which it drops into the discharge pipe. Here it strikes inclined baffles before being picked up by the primary air and carried to the burner.

Spalling of Refractories in Oil-Fired Furnaces

REFRACTORIES of furnaces fired by fuel oil usually fail by spalling rather than from slagging, whereas slagging is the more common trouble in furnaces fired with powdered coal. The relatively high ash content of coal may be accepted as an explanation for slagging but there has been no proven explanation of the common breaking up of the refractories walls by spalling, although that of strains caused by temperature variation has seemed the most reasonable one.

Furnace conditions of two large boilers, one using Illinois coal and one using fuel oil, have been studied by the Boiler Furnace Refractories Investigation, which the United States Bureau of Mines has been conducting in coöperation with the A. S. M. E.

Rates of heat liberation in the oil-fired furnace were much higher than that in the powdered-coal furnace but the maximum temperatures of the gases observed were about the same, or 2800 deg. F., although the maximum temperatures measured were somewhat higher in the oil-fired furnace at the positions where the flame impinged on the wall. The temperature gradient plotted for the first 6 in. of the hot side of the furnace wall under approximately constant operating conditions was not greater for the oil-fired than the coal-fired furnace.

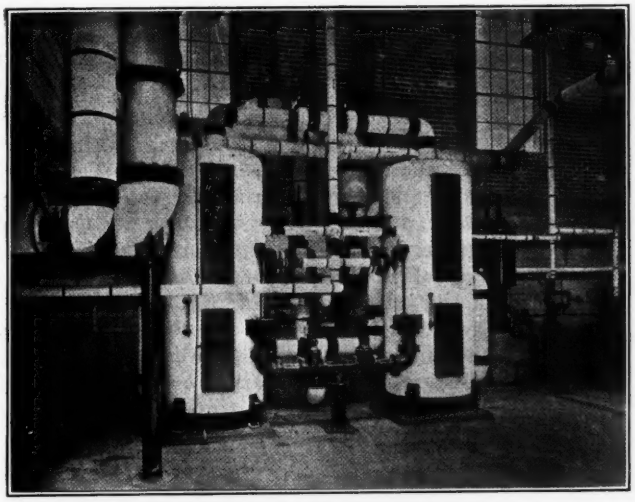
There is not sufficient evidence to warrant the acceptance of change of temperature as the only cause of the greater spalling in the oil-fired furnace and the differences in some of the other factors may be expected.

Chemical composition of the ash and slags has been made and it is possible that some mineral or minerals formed in the slag or in the combination of slag and brick makes them particularly sensitive to thermal shock, or else this mineral may have a different coefficient of thermal expansion from the brick; fracture resulted from the difference in the contraction when cooling. The relatively deep fractures found on the side and front walls bear out the former conception, while the thin fractures on the bridge wall bear out the latter.

AN ADDITION to the Riverton plant and a 30-mi. steel tower transmission line from Riverton, Kan., to the Neosho River plant of the Kansas Gas & Electric Co. at Service, Kan., effecting an interconnection of the two systems and providing for an interchange of power, have been completed by the Empire District Electric Co. at a cost of approximately $1,100,000.

This will make possible a pooling of resources of both plants for the benefit of either; will provide emergency standby service for both; will permit of extensive generating economies by both companies; and will provide an additional insurance of continued dependable lighting and power service to customers over the entire Empire system.

Interconnection of generating stations will provide a combined capacity of 175,000 hp. for the two companies and will complete a chain of interconnected generating stations through transmission lines from Wichita, Kan., to the Ozark dam at Ozark Beach, Mo.



Fuel Oil Handling and Storage Methods

TYPES, CONSTRUCTION AND LOCATION OF OIL STORAGE TANKS; EQUIPMENT AND CLEANING; METHODS OF OIL HANDLING; ARRANGEMENT AND EQUIPMENT OF OIL PIPE LINES; FLOW AND VISCOSITY OF OIL; TYPES AND LOCATION OF PUMPS; PRESSURES AND TEMPERATURES REQUIRED FOR BEST HANDLING; VARIOUS GRADES OF OIL AND METHODS OF HEATING EFFECTS OF OVERHEATING FUEL OIL

FUEL OIL IS USED for power purposes in two primary ways; for burning in boiler furnaces and for use in oil engines. In each case both light and heavy oils are used. By "heavy oils" is meant those oils which range from 30 to 22 deg. Baumé. Many plants find it advantageous to have their oil burning systems arranged so that either light or heavy oil may be used. This not only offers the advantage of a broader fuel market but also permits starting on lighter fuel and, after warming up, changing to heavier fuel. This is particularly true in the Diesel oil engine field. Except for the pressure and temperature requirements at the burner, handling and storage are carried out in a similar manner in both cases.

STEEL AND CONCRETE TANKS USED FOR STORAGE

Storage of oil is maintained in steel or reinforced concrete tanks, placed above, below or partly below the ground level. At Madison, S. D., the reinforced concrete fuel oil tanks for the Diesel power station are located under the cooling tower basin. Since they are low, they can be filled by gravity with oil from tank cars, dispensing with pumps and, since an approximately even temperature is maintained due to their level and to the warm water basin just above them, no heating means is required when pumping from them to the engine room daily supply tanks. In this case, the large pit is divided into several tanks so that both light and heavy oil may be stored.

Objection has been raised to combining water and oil storage in one system, on account of possible leakage of water into the oil storage tank. Such leakage will not occur if proper materials are used and proper precaution in construction taken. Detection of such leakage is simple, if the bottom of the oil tank drains to some low point from which a small pipe may be led and pumped out at regular periods to remove any water that may settle there. Concrete tanks may be used for the storage of fuel oil when the liquid is heavier than 35 deg. Baumé. The size should be not less than 13,000 gal. nor over 300,000 gal. capacity, the shape of circular section and strength designed to withstand full head of water corresponding to the tank depth. Oil should not be put into concrete less than six weeks old.

Steel tanks are usually cylindrical in shape, because it is stronger and less apt to leak, but square tanks are sometimes used in order to conserve room. If possible, tanks should be so placed as to provide proper drainage. If placed underground, the principal difficulties are to repair leaks and to detect the presence of settled water but underground location has the advantage that oil may drain back from the burners, if a valve is left open while the burner is inoperative. Some tanks are soldered as well as riveted at all seams in order to avoid leakage.

SLOPE OF GROUND USEFUL IN TANK LOCATION

Natural topography of the ground may indicate a slope alongside a power plant as the best location for oil storage tanks, in which case a railroad trestle may be

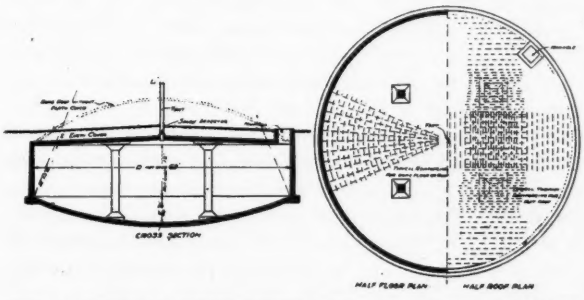


FIG. 1. TYPICAL REINFORCED CONCRETE FUEL OIL TANK

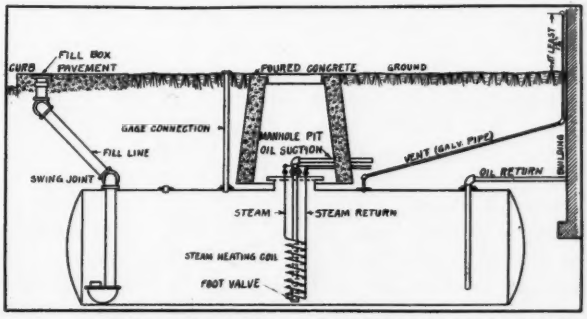


FIG. 2. STEEL OIL TANK ARRANGEMENT FOR SMALL BOILER PLANT

constructed over the tanks so that they may be filled by gravity from the cars.

Where pumping is required, rotary pumps are usually used for filling the tank. During cold weather the oil in the car should be heated by a steam coil placed close to the outlet of the car, as oils below 21 deg. F. are usually sluggish. Some tank cars are now supplied with pipe coils to which a steam line may be attached; specification that shipment be made in cars so fitted is, therefore, advisable during the winter months. In oil engine plants, hot circulating water from the jackets of engines is often used for heating.

Proper means for ventilating the tanks to carry off vapor and allow air to take the place of the oil that has

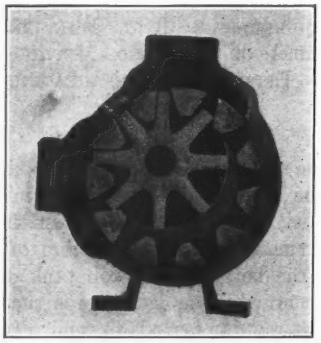


FIG. 3. SECTIONAL VIEW OF ROTARY OIL PUMP

been withdrawn, should be provided, as shown in Fig. 2. Ventilating pipes should terminate in a goose neck to prevent admission of dirt and water and a fine gauze screen should be fitted across the open end to prevent flames resulting from accidental ignition of the issuing vapors from striking back along the pipe into the tank. Means should also be provided to enable the operator to know, at any time, how much oil is contained in the tanks. Suction lines should be extended down to not lower than 1 ft. above the bottom of the tank so as to prevent settled water or sediment being drawn into the oil pipes.

By using two or more compartments in a concrete tank or two or more steel tanks, provision can be made for periodical cleaning. For this purpose, tanks should be fitted with man holes and steam or hot water used for flushing.

Arrangement and Equipment of Pipe Lines

Fuel lines should be provided with duplicate pumps, valving and pipe branches being provided so that either pump may draw its feed from any tank and serve any one or more burners. Drain collectors with gage glasses are provided for detecting leakage of oil past the heater tubes, thus avoiding risk of oil getting into the boilers except through the spray nozzle. Water is drawn from the collector for the purpose of observation about twice during a watch. Piping should be run as directly as possible, without sags, and so laid that, where possible, it pitches toward the supply tank without traps, provision being made for expansion, and to prevent jarring and vibration. There should be no dead ends in which sludge can accumulate and cause stoppage in the line and the pipes should be so arranged that the system can be completely drained in case of an extended shutdown. Automatic cutoff valves are installed in the line to shut off oil supply should there by any accidental stoppage of air supply to the burner. Spring loaded relief valves are installed between the pump and burners to prevent excessive pressure. Master valves, which may be placed at points remote from the furnaces, are used to control any number of burners by action of boiler steam pressure and fuel oil pressure to actuate oil and steam supply and control damper position. Wide range of regulation of supply to burners is effected by bypassing a quantity of oil, depending on the load, from the burner back to the supply or suction line of the pump. Metering of oil between the tank car and storage tanks, as well as between the tanks and the several points of consumption, is desirable. A perpetual inventory is thereby maintained and leakages or shortages are immediately detected.

Use and Location of Strainers Important

Strainers of the duplicate type are placed between the supply tank and the pump suction and in the oil feed line between the pump and burners, and small, fine mesh (20 to the inch) strainers should be placed at each oil burner. They are also attached at the inlet and at

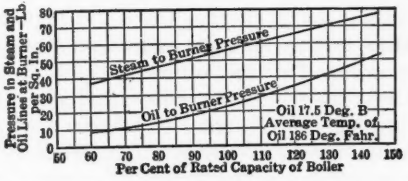


FIG. 4. RELATION BETWEEN OIL AND STEAM PRESSURE —STEAM ATOMIZERS, AUTOMATIC CONTROL

the outlet of each heater to provide for cleaning during operation. Pressure gages are also fitted on the inlet and outlet sides of the filter system so that need of cleaning may be observed. It is important that these strainers be kept clean; as a rule, they should be cleaned every 8 hr. of operation. When separating oil from water by heating coils, just sufficient temperature for the purpose should be allowed in the coil since vapor is given off by the fuel at a temperature a little below the flashpoint and any great amount of heating becomes dangerous.

Oil Transfer Methods

Oil may be transferred from the supply tank to the burner by gravity feed, by compressed air, by steam or, more commonly, motor-driven oil pumps, usually of duplex, reciprocating, or of rotary type. A unique design of the latter type is illustrated in Fig. 3. Reciprocating pumps must have brass valves and metallic or other packing that will not be affected by the oil and they should be provided with large air chambers to prevent pulsations of oil pressure due to the strokes of the pump, although some pumps are provided with governors for the purpose of maintaining a steady oil pressure. Such a chamber is sometimes of the nature of a standpipe. The maximum suction lift permissible for oil is about 16 ft., the speed of the pump not exceeding 20 strokes a minute. It is advisable to employ duplicate pumps.

Increase of pressure results in increase of steam generation. The relation between boiler rating and oil and steam pressure for a special case is shown in Fig. 5. Oil feeding for mechanical atomizing burners differs from that for steam burners only in the elimination of the steam line to the burners and in the use of higher oil pressures and temperatures. Pressure needed depends upon the viscosity of the oil and rate of combustion. It must be at least 25 lb. in order to produce good atomization and it may be as high as 200 lb.

Low-pressure systems for air atomization have been developed in which the air pressure employed is only 1½ lb. A head of only three or four feet is sufficient to cause oil to run freely into the burner; the higher pressure is required for atomization. Turbulence in the combustion chamber influences the pressure required, hence design is important.

Use of Right Temperature Important

Oil temperatures necessary to give best results in burning various grades of oil can best be found by experience. The temperature at which oil should be delivered to the burner depends upon the viscosity of the liquid. This should be sufficiently low to permit easy flow through the tangential passages and the orifice. A viscosity of 180 to 200 (Universal Saybolt) gives good results. If the oil is of greater viscosity than this at ordinary temperatures, it should be heated to a temperature which will reduce the viscosity to this point. This exact temperature depends upon the nature of the oil, heavy grade and thick oils usually requiring a higher temperature than light oils. Some oils will burn with no heating while some tar oils have to be highly heated. The viscosity of liquid fuel is not strictly a function of specific gravity. Oils of the same gravity but differing in viscosity, require different temperatures; certain approximations, however, such as given in the table, may be used as a general guide.

Atomization is improved by heating up to a certain temperature; beyond this, increase in temperature effects no further change but the flame becomes shorter and combustion occurs closer to the burner. No further change takes place in the viscosity of the oil but, due to the increased volume of the oil, the capacity of the burner is actually reduced.

Heating the oil beyond the vaporization point may result in a sputtering flame; pulsations may also occur, vibration in the furnace result and carbon deposit be formed in the pipes. Too low a temperature produces heavy smoke and imperfect combustion. Steam burners need a lower temperature of oil than mechanical burners because the oil is broken down by an outside agent. Results of tests on oil burners of the external atomizing type given in Figs. 6, 7 and 8 show the influence of temperature on the flow of oil.

RELATION OF SPECIFIC GRAVITY OF OILS AND THE TEMPERATURES TO WHICH THEY SHOULD BE HEATED

Specific Gravity of Oils Degrees Beaumé	Temperature to Which Oil Should Be Heated Degrees Fahrenheit	Specific Gravity of Oils Degrees Beaumé	Temperature to Which Oil Should Be Heated Degrees Fahrenheit
10.5	330	18.	185
11.	315	20.	160
12.	290	22.	140
13.	270	24.	125
14.	250	26.	110
15.	230	28.	95
16.	210	30.	85

Types of Oil Heaters

Oil heaters usually consist of a cylindrical outer shell surrounding a pipe coil or series of straight tubes. Heating may be accomplished by having the oil flow through the tubes or it may surround them; the heating medium, either steam or hot water, being on the opposite side of the coils or tubes. One type of oil heater employs the double pipe system in which a smaller pipe is surrounded by a larger one and the oil and steam flow in counter current. Another type of unusual design has a pair of helical, corrugated tubes, one inside of the other and both inclosed in a shell. The oil to be heated passes between the tubes while the steam is both inside and outside of the tubes.

Size of heater is determined by the formula $S = H \div k\ (t_s - t_o)$; where S = heating surface in sq. ft.; H = heat absorbed in B.t.u. per hr.; k = coefficient of heat transfer; = B.t.u. absorbed per hr. per sq. ft. per deg. difference in temperature; t_s = mean temperature of steam, deg. F.; t_o = mean temperature of oil, deg. F.

The coefficient, k, varies with the difference in temperature between the steam and oil and with the velocity of oil passing through or around the tubes. This velocity is of great importance as the greater the velocity, the better is the oil scoured from the side of the tube, thus allowing colder oil to come in contact with the hot surface.

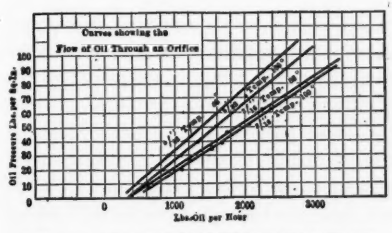


FIG. 6. CHART SHOWING FLOW OF OIL THROUGH ORIFICES OF STATED DIAMETER AT DIFFERENT TEMPERATURES. NOTE THAT FOR A GIVEN TEMPERATURE AND ORIFICE, THE RATE OF FLOW IS ALMOST DIRECTLY PROPORTIONAL TO THE PRESSURE

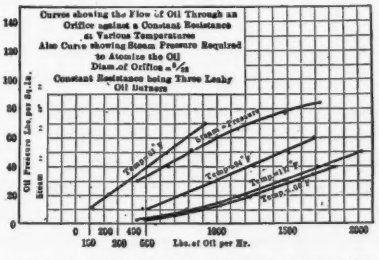

Curves showing the Flow of Oil Through an Orifice against a Constant Resistance at Various Temperatures
Also Curve showing Steam Pressure Required to Atomize the Oil
Constant Resistance being Three Leaky Oil Burners
Oil Pressure Lbs. per Sq. In.
Steam "
Lbs. of Oil per Hr.

FIG. 7. CURVES SHOWING FLOW OF OIL THROUGH AN ORIFICE AND LENGTH OF PIPE AT VARIOUS TEMPERATURES. TO THIS IS ADDED A CURVE SHOWING THE STEAM PRESSURE REQUIRED TO ATOMIZE THE OIL—ORIFICE 5/32 IN. DIA.

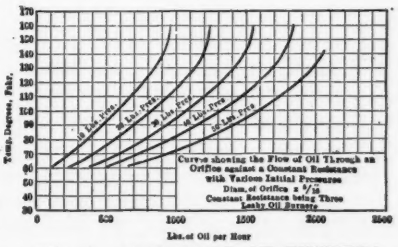
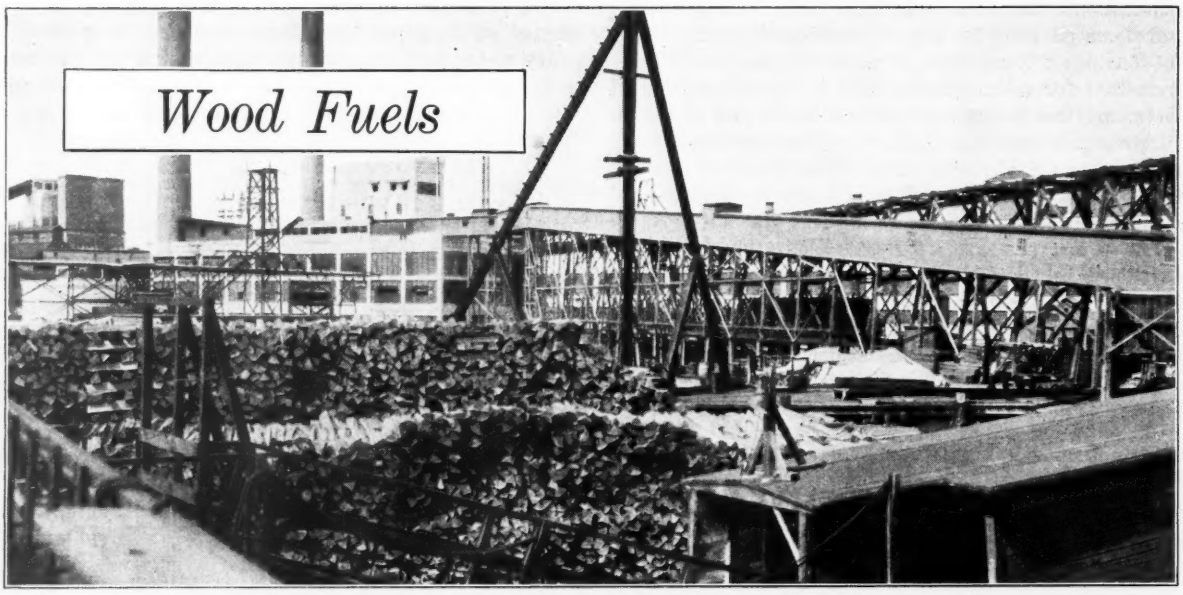

Temp. Degrees, Fahr.
Curves showing the Flow of Oil Through an Orifice against a Constant Resistance with Various Initial Pressures
Lbs. of Oil per Hour

FIG. 8. INFLUENCE OF TEMPERATURE ON THE FLOW OF OIL THROUGH AN ORIFICE AGAINST A CONSTANT RESISTANCE WITH VARIOUS INITIAL PRESSURES



Wood Fuels Require Proper Preparation

WHEN PROPERLY PREPARED, WOOD MAKES AN EXCELLENT FUEL. DETAILS OF HOGGING MACHINES OR SHREDDERS. FACTORS AFFECTING OPERATION

WOOD IS NOW used as fuel for steam raising plants in various parts of the country and the technique of handling it and burning has become fairly well standardized. When properly prepared and used in the correct type of furnace, wood is an excellent fuel, running, ordinarily, about 8600 B.t.u. per lb. when dry. Only in rare cases, however, is perfectly dry wood fuel available; in most instances it is delivered to the furnaces with a certain amount of moisture. Unless unusually high in content, this moisture does not interfere with proper burning.

Wood fuel, in most instances, is refuse fuel derived from some industrial process. The form in which it is available, therefore, depends largely upon the character of the industry from which it is derived and this, as must be obvious, varies greatly. It comes as sawdust, shavings, slabs, blocks and edgings and in various mixtures. Sawmill refuse, for instance, contains wood of every kind and size from fine sawdust to blocks of wood as large as 12-in. cubes. Refuse from furniture factories is also quite variable and comes as shavings, sawdust and blocks, although here the blocks are of smaller size.

Hogging or Shredding

While it is possible to burn such mixtures it is usual to produce a more uniform size fuel by reducing the size of the large pieces. This is called hogging or shredding, and is done in machines fitted with a number of rotary knives or hammers. These machines are available in various types, a typical one of which is shown herewith.

With the exception of reducing the wood blocks to the proper size for use in the furnace, little preparation is necessary. No attempt is made, usually, to remove moisture by drying. Where wet fuel is used, a different type of furnace is used which evaporates most of the moisture as it first enters the furnace; in fact, in some installations the fuel is actually sprayed with water as it enters the furnace in order to give it a certain moisture content. This is sometimes desirable where the fuel is extremely dry and light and where it is burned under forced draft.

Details of Shredding Machine

A cross section of a typical "hog" or shredder is shown in Fig. 1. This particular machine is known as a swing hammer type of shredder. It consists of a heavy cast-iron casing, mounted on a lower frame of one piece, in which is contained the rotating member. The latter is made up of a heavy steel shaft carrying a number of hammers, which pass in close proximity to a number of shredding bars, which are finished with sharp cutting edges. As the wood is caught between the rapidly rotating hammers and the shredder bars, it is split and the smaller pieces are discharged downward through the spaces between the bars.

Various types of shredder bars are available for machines of this kind producing various sizes of fuel. The bars are held at the proper spacing by saw-toothed malleable iron racks which rest on ledges formed in the sides of the frames of the machine. These racks divide the entire screening surface into three or four panels which may be handled as a unit when assembled with the proper number of bars.

When constructed in this manner, a shredder can be adapted to a wide variety of conditions. Decayed or damp soft wood will not pass through as fine a screen

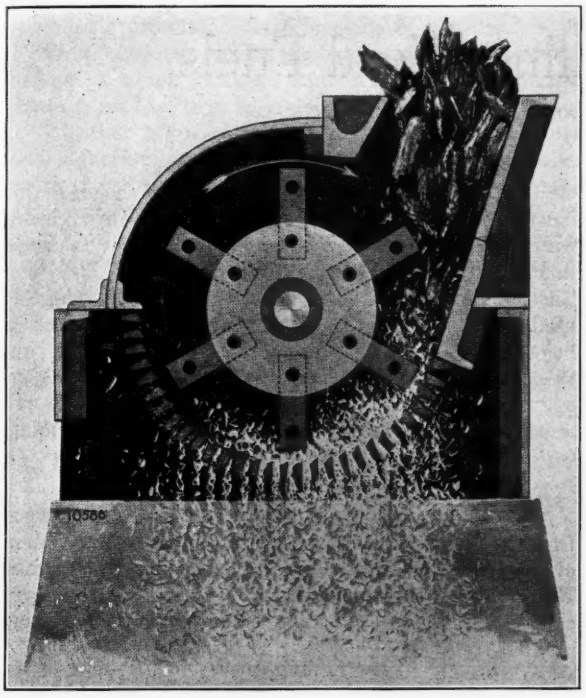


FIG. 1. CROSS SECTION OF A SHREDDING MACHINE USED IN REDUCING SIZE OF WOOD BLOCKS AND SLABS

as will hard dry wood. For some classes of wood, it is desirable sometimes to have different meshes of bars in different portions of the screen cage. The bar and rack system is particularly adapted to this condition.

For making sawdust from planer shavings, the screen plates shown in Fig. 3 can be used in the shredders. These are perforated metal plates bent to shape and properly stiffened.

In this type of shredder, the hammers are pivoted loosely at the shaft end and when rotating are held radial to the shaft by centrifugal force. When in operation, the rows of hammers act the same as the blades of a centrifugal fan. The current of air created, combined with the centrifugal force of the hammers rotating at high speed, tends to force the material being reduced beyond the reach of the hammers.

The speed, power required and output of shredders

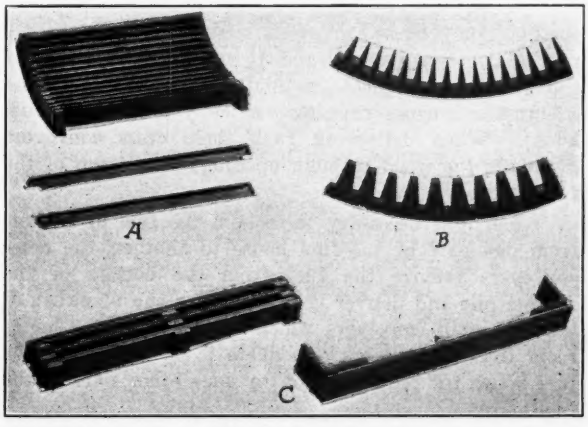


FIG. 2. RACKS AND BARS FOR USE IN SHREDDERS

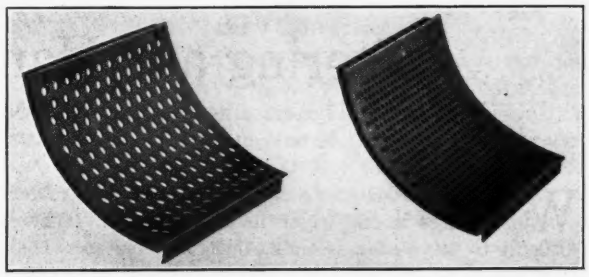


FIG. 3. SCREEN PLATES FOR MAKING SAWDUST

vary considerably with different kinds of wood and its condition—whether wet or dry, green or seasoned, etc.; also with the degree of the reduction to be obtained. A high speed usually cuts through the material more easily and uniformly than a lower one. Speed does to a great extent control the degree of reduction to be obtained. The higher the speed, the greater the reduction.

TABLE I. APPROXIMATE SPEED, AND POWER FOR VARIOUS SIZES OF SHREDDER

Size Shredder inches	Speed in r.p.m.	Approximate horsepower
20 × 12	1600 to 1800	15 to 20
24 × 18	1400 to 1600	20 to 30
30 × 24	1200 to 1400	30 to 40
36 × 24	1100 to 1300	40 to 65
36 × 30	1100 to 1300	70 to 90

TABLE II. APPROXIMATE CAPACITIES IN TONS PER HOUR

Size of Shredder in.	Chestnut logwood, Pine chips, etc., ¼" bar opening	Medium size wood refuse for blower systems or conveyor 1" bar openings	Planer shavings, Pine and similar woods reduced to sawdust ¼" round perforated plate
20 × 12	¾ to 1	⅓ to ⅔	¼ to ½
24 × 18	1 to 2	½ to ¾	½ to ¾
30 × 24	3 to 4	1 to 2	¾ to 1
36 × 24	5 to 6	1½ to 2½	1 to 1½
36 × 30	7 to 8	3 to 4	1½ to 2

In the accompanying tables are shown the approximate speeds, power and capacities for the type of shredder shown in Fig. 1. These figures are typical but should not be regarded as absolute since variable factors may cause considerable difference.

ADJACENT TO the new State highway and on the Burlington Railroad, the Consumers Public Service Co. has completed a new modern ice plant in Brookfield, Missouri. It has a capacity of 45 t. of ice daily and a storage capacity of 750 t. It is built of concrete and brick, the walls being of red press brick trimmed with cream-colored terra cotta.

The plant contains a 10-car icing platform for icing C. B. & Q. cars on the Brookfield Division. The produce and fruit cars are initially iced and re-iced at this point and the platform contains the latest type of elevator and conveyor. Cars are iced with either crushed or lumped ice, as the shipper desires. The plant contains 560 cans which are handled in groups of four.

Ammonia compressors are driven by direct connected synchronous motors. The plant is equipped with the latest type scoring machine, which not only simplifies the handling of ice by employes, but assures all customers uniform weight. It also has a cube machine for the making of clear, pure water cubes for table use.

Storing and Handling Wood Fuels

PRACTICE IN STORING WOOD OUTDOORS AND INDOORS. CONVEYORS AND EQUIPMENT USED IN HANDLING, FEEDING FUEL TO FURNACE

WHERE WOOD waste is used as fuel, the problem of storage is one which in many respects is more difficult to solve than is that of storing coal in a coal-burning plant. Wood waste is considerably more bulky than coal and has a tendency to settle into a hard, compact mass when stored for any considerable length of time, which makes its removal very difficult at times.

FIG. 1. LARGE OUTSIDE WOOD STORAGE PILE AT STATION L OF THE PORTLAND ELECTRIC POWER CO., AT PORTLAND, OREGON

In storing wood refuse, it is most convenient to store it in the hogged or shredded form or as sawdust since in any of these forms it takes up less space than if in the form of slabs or blocks. The unit of measurement employed in storing and handling wood refuse is usually the equivalent of the cord, approximately 200 cu. ft. and weighing from 2500 to 4000 lb. depending upon the kind of wood, its size and the moisture content. If the question of storage alone is considered, this unit serves fairly well, but where it is bought or sold in large quantities this unit is subject to criticism, because of the many variables involved. A more equable unit would be one taking into account the weight, the moisture content and the heat value. Such a unit has been suggested and has been used but, in most instances, the unit of 200 cu. ft. is the only unit of measurement.

Outdoor Storage

Like coal, wood refuse is stored either out of doors or indoors. When stored outdoors some form of drag scraper is usually employed to handle it. Because of its comparatively low cost as compared to coal, wood storage as a rule does not justify the use of expensive bridge cranes or other forms of conveying and handling equipment commonly used with coal. In Fig. 1 is shown a view of a large outside wood refuse storage pile at Station L of the Portland Electric Power Co. at Portland, Oregon. This plant is tied in with a large hydro-electric system and a large amount of hogged fuel must be kept in storage to carry the plant through low water periods. Another large outside storage is shown in Fig. 2, which is that maintained at the St. Paul and Tacoma Lumber Co. at Tacoma, Washington. The fuel used here is refuse from the lumber mills which is hogged and depending upon the kind of wood, runs from 30 to 70 per cent moisture. This particular storage is served by a drag scraper fitted with a rake and is used both for placing fuel in storage and reclaiming.

Inside Storage

One of the most elaborate and best equipped wood fuel storage systems in the country is that at the plant of the Long Bell Lumber Co. at Longview, Washington. Here, hogged fuel from the mills is stored in a large concrete fuel house with an elaborate system of con-

FIG. 2. OUTSIDE WOOD STORAGE AT PLANT OF THE ST. PAUL AND TACOMA LUMBER CO., TACOMA, WASH.

veyors for storing and reclaiming the fuel as may be necessary.

This system is extremely interesting and is shown diagrammatically in Fig. 3. Fuel is delivered to the fuel house at both ends by a conveyor running from each of the mills, these being designated A and B on the diagram. These conveyors, in turn, deliver to either of the two conveyors C and D running lengthwise of the fuel house. These, in turn, deliver to any of the 12 cross conveyors running vertically around the fuel house. When delivering fuel, these cross conveyors discharge the wood through openings in the top of the fuel house.

When it is necessary to reclaim the fuel or shift it from one part of the fuel house to another, the cross conveyors remove the fuel from the bottom of the storage pile and deliver it to the lower run of either of the two main conveyors which deliver it to the boiler room feeder conveyors or elevate it to the top of the fuel house for redistribution to some other part of the fuel house.

This system is extremely flexible and operates with

very little attention. It represents a considerable investment, however, which probably would not be justified at a much smaller plant where only a limited quantity of fuel is to be stored.

In other types of inside storage, similar but much less elaborate arrangements are used. In the boiler room, the storage usually takes the form of an overhead bin from which the fuel is fed to the furnaces by means of belt, flight or screw conveyors. Sometimes agitators are installed in the storage bins which prevent the fuel from arching.

Handling and Transporting Wood Fuel

Even more than the question of storage, the problem of transporting and handling wood refuse in wood burning plants is one of considerable importance and in most instances the solution depends largely upon

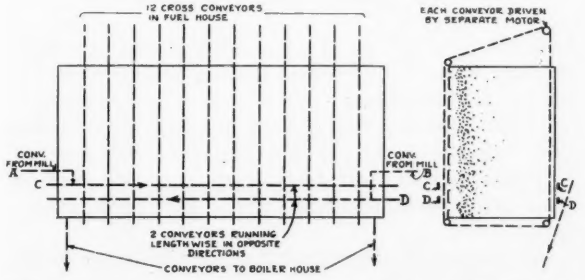


FIG. 3. DIAGRAM SHOWING THE ARRANGEMENT OF CONVEYORS IN THE FUEL STORAGE HOUSE AT THE LONG BELL PLANT

local requirements. Wood fuel is transported in many ways; if in the form of sawdust or shavings it can be blown through pipe lines; if the particles are larger, any of a number of different mechanical conveyors may be used. Belts and flight or scraper conveyors are common and for short distances the screw conveyor is sometimes used. In many plants a combination of methods is necessary. Where it is to be transported over long distances, say from a saw mill to a manufacturing plant, water transportation by barge is perhaps the most economical. Wood fuel is rather bulky for ordinary railway transportation but where this is

FIG. 4. SECTION OF FLIGHT CONVEYOR SHOWING A FORM OF DETACHABLE LINK CHAIN AND WOODEN FLIGHTS

necessary, cars with special large bodies are often provided.

In small plants, the ordinary flight conveyor is used considerably. It is simple to install and its maintenance with wood fuel is low. A short section of a typical scraper conveyor used in handling wood fuel is shown in Fig. 4. This particular conveyor is made with a detachable link chain with wood flights bolted to special attachments about every 18 in. These flights scrape the material along by dragging it in a trough. Conveyors of this type can be made any length up to 300 ft. and may ascend any angle up to 45 deg.

Belt Conveyors

Where wood fuel is to be conveyed over longer distances, the belt conveyor can be installed to advantage. An interesting installation of belt conveyors for this purpose is that at the plant of the Long Bell Lumber Co. referred to above. At this plant, in addition to that used in the boiler house, a considerable quantity of hogged fuel is sold to power plants along the Columbia River. Here a system of five, 48-in. belt conveyors totaling 1500 ft. in length has been installed to convey the fuel from the hoggers to the wharf on the river. These conveyors feed from one to the other and are each driven by a separate electric motor. An important part of this installation is the control of the motors, these being interlocked so that when one stops the entire system stops. Figure 5 shows barges being loaded with hogged fuel at the Long Bell plant.

For handling the hogged fuel in the fuel house at the Long Bell plant, scraper conveyors are used. In this case, the flights are of steel, fastened to cables running over gapped sheave wheels. The details of this arrangement are best seen in Fig. 6, which is a view taken on the outside of the fuel house.

FIG. 5. BARGES ON THE COLUMBIA RIVER BEING LOADED WITH WOOD REFUSE AT THE PLANT OF THE LONG BELL LUMBER CO.

For loading overhead fuel bins in boiler rooms, the bucket elevator type of conveyor used with coal is often used. This works out very well but with fine sawdust, the enclosing duct must be made exceptionally tight. A view of an elevator conveyor of this type installed at the Spokane Central Heating Co. is presented in Fig. 7. Considerable trouble was experienced with this installation when it was first installed due to the leakage of sawdust but this has been rectified by thoroughly tightening all the joints and seams in the galvanized iron casing which encloses the elevator.

Feeding Fuel to the Furnaces

Various arrangements are used in feeding wood refuse to the furnace but in most cases the principles involved are the same. In general it is the practice to feed the fuel into the top of the furnace which is usually of the Dutch oven type, in a continuous stream. Unless the fuel is exceptionally fine and dry, it will pile up on the grates (providing flat grates are used) in the form of a cone, combustion taking place at the surface of the cone as the moisture dries out.

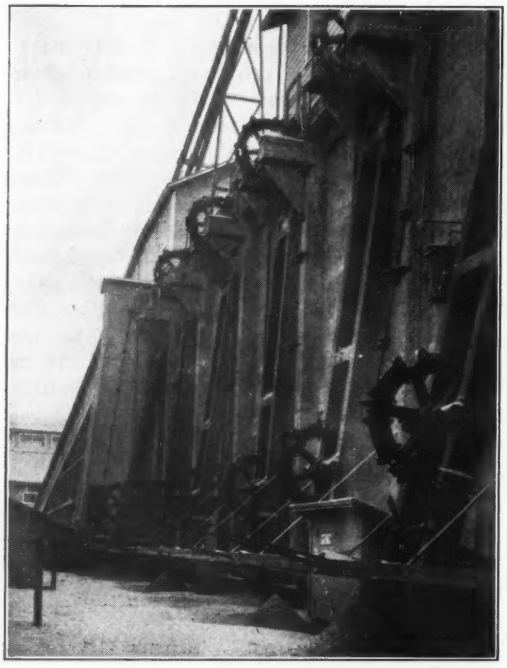


FIG. 6. VIEW TAKEN ON THE OUTSIDE OF THE FUEL HOUSE AT LONG BELL SHOWING THE TYPE OF CONVEYORS USED

Arrangements employed for feeding the fuel vary in complexity, from simple chutes leading from a belt conveyor to the furnace such as shown in Fig. 8 to arrangements involving an elaborate combination of screw conveyors and special feeding devices as shown in Fig. 9. A diagram of this latter arrangement together with a detailed view of the paddle wheel feeding device is shown in Fig. 10.

An arrangement such as shown in Fig. 9 is very satisfactory as the rotary feeder keeps out excess air, prevents avalanching and reduces the fire risk due to back fire. As will be noted, a screw conveyor removes the fuel from the bottom of the bin and delivers it to the top of the furnace.

FIG. 7. BUCKET ELEVATORS USED FOR WOOD FUEL AT A CENTRAL HEATING PLANT

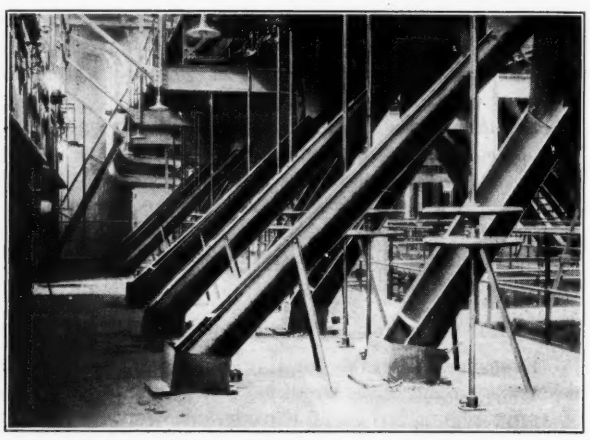


FIG. 8. CHUTES FEEDING WOOD FUEL INTO THE TOPS OF DUTCH OVEN FURNACES

Where fine dry fuel is used, the feature preventing back firing is important and is particularly necessary in plants getting their fuel direct from furniture and other wood working plants where kiln dried stock is used.

In plants burning refuse from saw mills and lumber plants, less attention need be paid to this point of preventing back fire. The refuse from such plants usually contains a considerable amount of moisture and as a consequence the danger of sudden ignition is remote. In some plants burning sawmill refuse on the Pacific coast the moisture content of the fuel runs as high as 50 and 60 per cent.

Where wood fuel is burned under forced draft it is sometimes necessary where the fuel is dry to wet it before feeding it into the furnaces, so as to prevent its being blown out of the furnace. In such cases a water spray is often placed in the chute leading to the furnace.

In feeding wood fuel there is sometimes a tendency for the fuel to arch in the bins or pack the chutes to the furnaces. For this reason the bins must be con-

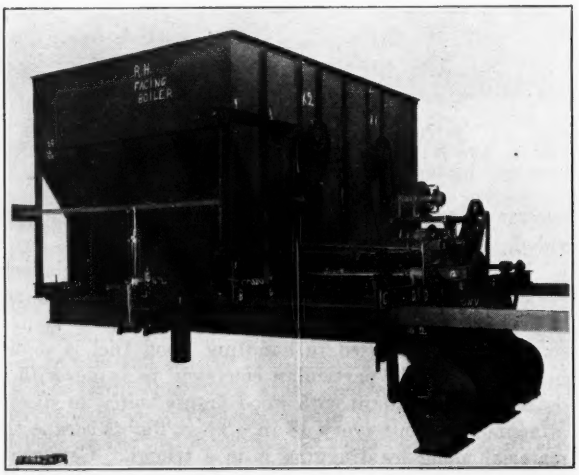


FIG. 9. COMBINED STORAGE BIN WITH SCREW CONVEYORS AND FEEDING DEVICES USED FOR WOOD FUEL

structed with smooth sloping sides and all chutes and ducts leading to the furnace must be at an inclination sufficient to insure an easy flow of fuel. Even under these conditions it often arches but the trouble is usually easily overcome by tapping the sides of the bins or chutes.

The proper method of feed must as a rule be worked out for each plant in accordance with local conditions and the characteristics of the fuel. Where the load on the boilers is fairly steady a constant feed subject to hand control is often satisfactory but where fluctuating loads are encountered, the feeding device may be controlled automatically from the steam pressure by some sort of regulating device.

In one plant on the west coast, a satisfactory hand control system was developed by driving the main flight conveyor through a speed variator of the mechanical

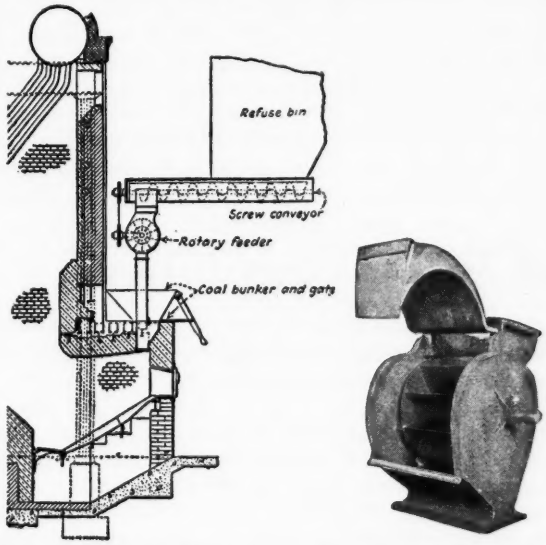


FIG. 10. SECTION SHOWING ARRANGEMENT OF EQUIPMENT SHOWN IN FIG. 9 APPLIED TO BOILER FURNACE AND DETAIL OF ROTARY FEEDER

type. A number of speed variators are on the market which give a wide range of speeds by merely manipulating a small hand wheel on the apparatus.

A similar arrangement is provided on the apparatus shown in Fig. 9 only, in this case, the control of the speed variator is accomplished automatically by the regulator shown at the left of the fuel bin. In this apparatus, the bin is provided with an agitator to prevent the fuel from arching.

ACCORDING TO a paper presented by A. G. Christie at the recent Bituminous Coal Conference, the use of preheated air supplies in the furnace is increasing rapidly and results in improved furnace performance. This coupled with the desire for greater boiler outputs has led to the wide adoption of water-cooled furnace walls. The use of such walls will continue to extend in both stoker and powdered coal furnaces. Such construction provides maximum fuel burning capacity for a given furnace and reduces maintenance. Furnace volumes will in the future be worked at greater capacities in consequence of the preceding developments.

Dust Explosion Prevention in Wood Burning Plants

CLEANLINESS IS PRIME REQUISITE IN ELIMINATING DUST EXPLOSION HAZARDS

FROM A CAREFUL consideration of reports of dust explosions in various industries, it is evident that the danger of explosion in wood burning power plants is considerably less than it is in many other industries. The degree of danger present depends largely upon the character of the wood burned. It would hardly be expected that dangerous explosions would occur in sawmills, for in these plants much green lumber is present and the sawdust produced is fairly high in moisture content. Furthermore, such plants are usually of open construction, a factor which in itself is not conducive to the promotion of dust explosion.

That there is a dust explosion hazard in wood dust in certain types of plants is evident from the history of a number of wood dust explosions that have occurred. As early as the year 1874, eleven workmen were seriously injured in an explosion in a wood working plant in Detroit, Mich. A brick flue extending through several floors of the building had openings on each floor into which refuse such as dust and shavings was put, to convey it to the furnace room. A steam pipe passed through this flue about 8 ft. from the furnace room floor. A fire starting at this point had just got under way when a quantity of dust and shavings was thrown down the flue. These were ignited and the explosion resulted.

REPORTS OF EXPLOSIONS

In 1906, at Fitchburg, Mass., an explosion occurred when a new dust collecting system in a wood working plant was being tried out. Here dust was being blown into a collector having a feed pipe directly in the boiler room. Dust which had worked into the system was blown into the boiler room as the new equipment was started. The furnace doors being open at the time, the dust ignited and caused an explosion which propagated through the plant.

In another case in St. Louis, Mo., an explosion occurred when an employe carrying an open lantern entered the shavings house.

In August, 1910, an explosion of sawdust occurred at Barber, Calif., wrecking the power house, three of the walls being demolished and the roof blown off.

These few cases out of a list of 15 serve at least to indicate that there is danger from dust explosion in plants burning wood fuel, particularly when in the form of fine sawdust and shavings.

In general, the finer the particles of dust, the greater the danger from explosion; hence, extreme precaution is necessary in wood working plants where polishing and sanding of wood is done, since the wood dust produced in these operations is very fine and dry.

ELIMINATING EXPLOSION HAZARDS

In the prevention of dust explosion, two main factors must be considered, first the prevention of a source of ignition and second the prevention of an explosive mixture. While the prevention of explosive mixtures

is of great importance it is nevertheless a fact that before there can be an explosion there must be a source of ignition. This may be considered the real cause of an explosion, and if the sources of ignition can be eliminated explosions will no longer occur. There is no such thing as spontaneous combustion in the explosion of dust. A pile of dust cannot explode like dynamite or black powder or other detonating explosives. Fine dust can explode only when intimately mixed with air as a cloud. Consequently there can be no such thing as an explosion of a pile of dust, whether flame gets into it or not, as long as the dust remains in a pile. Even should a pile become ignited due to spontaneous combustion, therefore, it would merely burn without exploding. There is no such thing as spontaneous explosion.

Causes of Dust Explosions

A number of definite causes of dust explosions and methods of eliminating the sources of ignition have been established. Without entering into a detailed discussion of these various causes, they may be listed as follows:

1. Smoking and carrying of matches in plants.
2. Use of open flames and lights, such as torches, gas lights, lanterns, candles, etc.
3. Small scale fires caused by general sources of ignition which may come in contact with a cloud of dust in the plant.
4. Electrical causes, such as sparks from motors, fuses and switches, short circuits, the breaking of incandescent lights and the firing of dust accumulated on the lamps.
5. Sparks struck by foreign material going through a grinding machine.
6. Static electrical discharge.
7. Choke ups and friction in elevators.

The remedies for each of these conditions are obvious. As to the control of explosive mixtures in plants, a volume could be written and yet all the factors probably would not receive full discussion. In wood burning power plants, the prime requisite is cleanliness. If there is no accumulation of wood dust and the plant is perfectly clean, the explosion cannot propagate. In keeping the plant clean care must be observed in sweeping. Careful sweeping does not stir up much dust but the usual sweeper is none too careful and often, in sweeping, he produces the very mixture of dust and air which, by keeping the plant clean, he is trying to avoid. The development of efficient vacuum cleaning systems for industrial plants is a step in the right direction and their intelligent use will do much to eliminate the dust explosion hazard.

Gas Makes Ideal Fuel When Available

Natural, Blast Furnace and Coke Oven Gas Make Good Boiler Fuel, But Use Is Limited to a Few Localities or Industries. Storage Not Practical and Standby Fuel Is Always Provided

NATURAL GAS, because of the cleanliness, ease of control and low labor charge, is favored for boiler fuel where the supply is such that a sufficient quantity is available for industrial use at a competitive price. Blast furnace gas and coke oven gas are also widely used in industries when they are produced as a by-product, as in iron and coke plants. Like mineral oil, natural gas is formed from organic matter and consists of hydrocarbons, mainly methane and marsh gas. It is a rich gas, running around 21,000 B.t.u. per lb., although gases from different fields vary widely.

Coke oven gas contains over 80 per cent hydrogen and hydrocarbons, about 10 per cent nitrogen and about 6 per cent CO. It is distilled from coked coal and the heating value runs around 14,000 B.t.u. per lb. Blast furnace gas, formed in the process of reducing iron ore has in the neighborhood of 60 per cent nitrogen, some hydrogen and CO_2 and a considerable percentage of CO which is largely responsible for the heating value of about 1200 B.t.u. per lb.

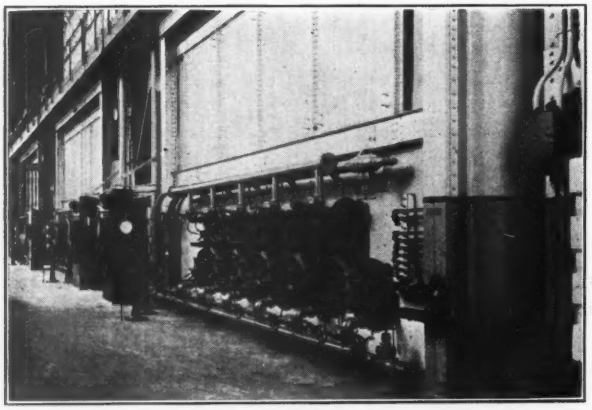


FIG. 1. TYPICAL GAS-FIRED BOILER WITH COMBINATION GAS AND OIL BURNER

At 32 deg. F. and 29.92 in. of Hg., the specific volumes of the gases are in the neighborhood of 22.5, 25, and 12.5, respectively, for natural, coke oven and blast furnace gases giving heating values of, roughly, 1000, 600 and 100 B.t.u. per cu. ft. of gas.

Blast furnace gas is ordinarily burned at from ½ to 50 in. of water, depending upon the design of the

STANDARD BLACK AND GALVANIZED IRON PIPE DATA

Size	Diameter		Ft. of pipe for 1 cu.ft. of Volume
	Int.	Ext.	
1/4	0.364	0.540	1385.
3/8	0.493	0.675	751.
1/2	0.622	0.840	472.
3/4	0.824	1.050	270.
1	1.049	1.315	167.
1-1/2	1.610	1.900	71.
2	2.067	2.375	42.
2-1/2	2.469	2.875	30.
3	3.068	3.500	19.
4	4.026	4.500	11.
5	5.047	5.563	7.2
6	6.065	6.625	5.0
8	8.071	8.625	2.9
10	10.192	10.750	1.8
12	12.090	12.750	1.3

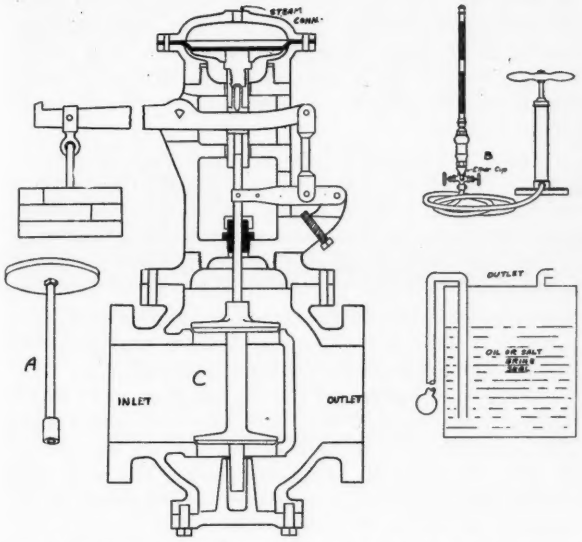


FIG. 2. EQUIPMENT APPLICABLE TO GAS SYSTEMS: A—SWAB FOR CLEANING PIPE; B—PROVING OR TEST PUMP FOR DETECTING LEAKS IN PIPING; C—AUTOMATIC GAS REGULATOR; D—LIQUID SEAL LOW-PRESSURE SAFETY VALVE

burner. The majority of burners, however, work best at from 3 to 10 in. At the engines, the gas pressure ordinarily runs from 18 to 20 lb. but the pressure is reduced to the lower value at the burner, either through friction drop through the lines or by throttling. Velocities through the mains in actual installations range from 40 to 50 ft. per sec., based upon standard conditions.

This gas is too lean to store and is ordinarily used as it is available; oil, stokers, or pulverized coal being used as standby fuel and to fill in the peaks between the steam demands and gas supply.

Standby Fuel Always Provided with Gas

Natural gas has not received as much attention for power plant work as other fuels, largely because its availability for industrial purposes at competitive prices is limited. It is available only a part of the year or

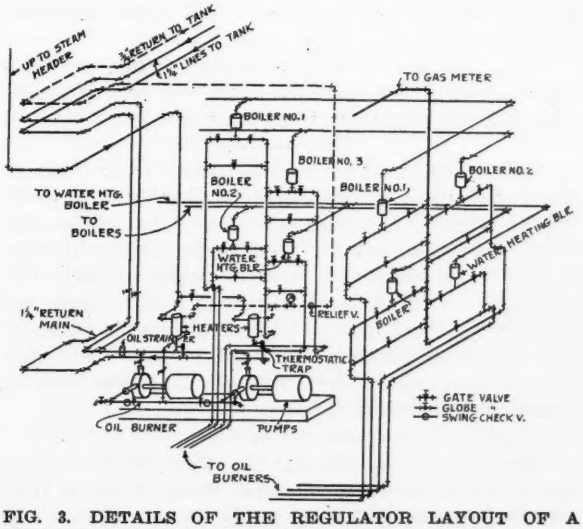


FIG. 3. DETAILS OF THE REGULATOR LAYOUT OF A TYPICAL GAS-FIRED INSTALLATION USING FUEL OIL AS STANDBY

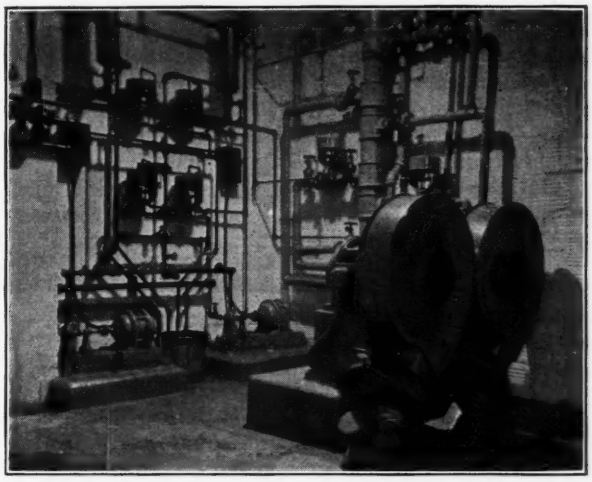


FIG. 4. PHOTOGRAPH OF THE EQUIPMENT SHOWN IN FIG. 3. THE PUMPS AND BLOWERS ARE USED WITH THE FUEL OIL ONLY

when new fields are opened. For this reason, oil or coal is always used as a standby. Burners are available which will burn gas, oil, or pulverized coal without change.

Usually gas reaches the power plant at from 85 to 100 lb. pressure and is reduced to about 20 lb. for metering. It is then further reduced to the burner pressures, which ordinarily vary from ½ to 10 oz., depending upon the characteristics of the individual burner. Natural gas is stored to a certain extent by producers largely in natural reservoirs, but is not stored by individual users because the expensive storage facilities would not be justified. Standby fuel is used instead.

Standard iron piping can be used, the accompanying table giving data regarding weights and capacities of standard sizes. Many cities and companies have regulations governing installation of gas pipes and these should be carefully followed. Piping layouts should be as direct as possible and all pipe before being used should be cleaned by standing on end and hammering and should then be blown out with compressed air.

Damage of Piping Is Important

A satisfactory swab which can be made for any size pipe is shown in Fig. 2A. This consists of a short length of small pipe upon which is fastened a leather washer held in place by two iron washers, slightly smaller than the leather. White lead or other jointing material should be used sparingly and then only on the male thread.

Piping should never be laid with a sag, but should slope toward the meter or toward an outlet from which moisture can be removed if necessary. In some cases, sand and oil traps or separators are advisable. When necessary to imbed a pipe in concrete or cement, black iron pipe can be used unless the concrete is exposed to some corrosive liquid in which case a protective covering or paint should be used. Red lead or bituminous paints can be used for this.

Welded pipe is coming into wide use for this service, especially for the large low-pressure gas mains used for by-product cases. After completion, the piping should be given a pressure test by means of compressed air. Fig-

ure 2B shows a small test or gas proving pump, used for this purpose. Pressure can be measured by means of a mercury or water manometer or ordinary spring gage, drop in pressure being an indication of leakage. Leaks can be detected by smell if a small quantity of ether is injected into the pipe. This is preferably done by means of an ether cup on the test pump.

In calculating header or pipe sizes, the supply pipes to the individual burners can be used as a basis, a convenient formula being:

$$A = \sqrt{B \times C}$$

where

A = diameter of supply pipe in inches
B = area of gas connections to burner
C = Number of burners used.

For calculating long pipe sections, the following equations, based on the work of the U. S. G. S. for the

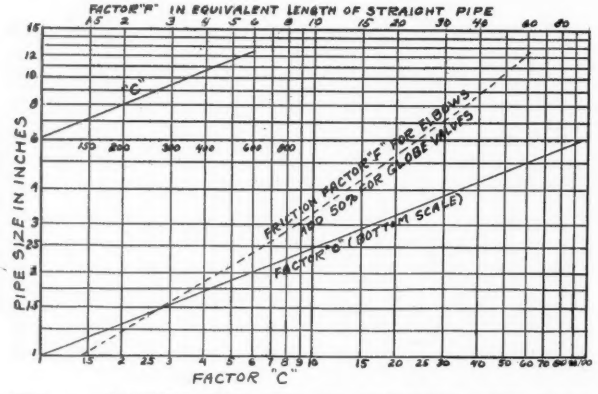

FACTOR "F" IN EQUIVALENT LENGTH OF STRAIGHT PIPE
PIPE SIZE IN INCHES
FACTOR "C"
FRICTION FACTOR "F" FOR ELBOWS AND 50% FOR GLOBE VALVES
FACTOR "C" (BOTTOM SCALE)

FIG. 5. FACTORS FOR USE IN FIGURING PIPE LINE CAPACITIES AND FRICTION FACTORS OF ELBOWS

flow of natural gas with a specific gravity of 0.6 through a 1-in. pipe, can be used to give approximate sizes.

$$Q = C\sqrt{\frac{10D}{L}}$$

where

Q = flow in thousands of cu. ft. per hr.
D = pressure drop in lb. per sq. in.
L = length of pipe in feet
C = pipe diameter factor

As this equation is based on 1-in. pipe and gas with a specific gravity of 0.6, corrective factors must be applied for other conditions. The specific gravity correction to Q is equal to the square root of 0.6 divided by the actual specific gravity. These values are 0.894, 0.925, 0.960, 1.000, 1.044 and 1.094, respectively, for specific gravities of 0.75, 0.70, 0.65, 0.60, 0.55 and 0.50. Values of the factor C can be obtained from the curve, Fig. 5.

Pressure regulation is ordinarily handled automatically by a valve, one type of which is shown in Fig. 2C. The diaphragm chamber is connected to the steam header. Details of a well-laid-out industrial installation are shown in Figs. 3 and 4. Gas is normally used with oil as a standby. Combustion control is automatic.

Another installation, a central station with eight 600-hp. boilers, is laid out as follows: Gas arrives at the plant through an 8-in. line tapped off a 12-in. main. At the plant the 8-in. line enters a manifold from which there are two metering pipes, one 8-in. and one 4-in., leading to a second manifold. The 8-in. pipe has an automatic valve set to open at 80 in. differential across the meter orifice and to close when the differential falls below 20 in.

From this metering installation an 8-in. header enters the boiler room basement and extends the length of the boiler room directly under the boilers. Each boiler is fed through a balanced valve regulator set for 8 oz. On the low-pressure side of the regulator there is a 4-in. safety valve set for 1½ lb. discharging into a 4-in. header which exhausts outside of the building just below a doorway into the boiler room where any continued leakage would be quickly detected by the odor.

There is a butterfly valve in the 8-in. riser to the burner header and a 4-in. gate valve at each burner. The butterfly valve is used only to shut off gas quickly in case of a rapidly dropping load. The 4-in. gate valves are used for all ordinary adjustments of gas supply.

Each installation requires individual treatment, of course, to meet local conditions, but the above is typical practice. An oil or salt brine sealed safety outlet is shown in Fig. 2D. The inlet pipe extends nearly to the bottom of the tank and is sealed with liquid to a depth which will give a sufficient back pressure.

Welded Building Construction

RECENTLY was completed by the Austin Co. in Cleveland, Ohio, the Upper Carnegie Building which has no rivets or bolts in its construction. Members of the frame were specially selected and designed for erection by arc welding and all joints were made by this process, the welding being done by the Lincoln Electric Co.

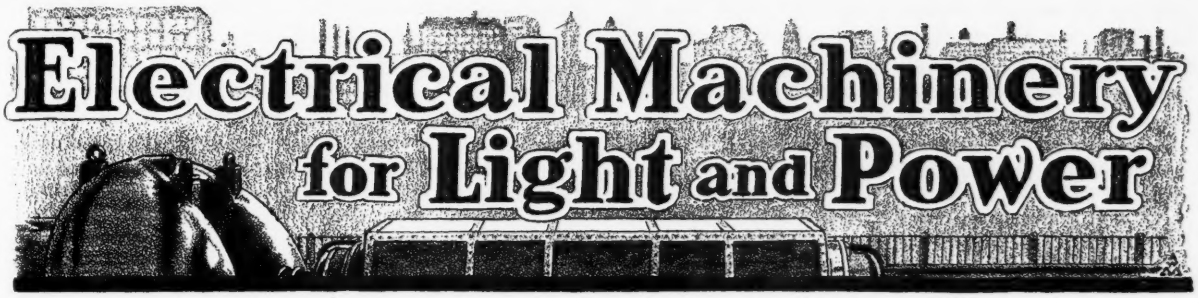
It is a four-story building, 60 by 119 ft., with store rooms on the first floor and offices in the remaining stories. Saving of 15 per cent in steel tonnage is estimated. Columns and beams were made continuous by welding, stiffener and base plates were welded in place and lattice girders were built with welded joints.

Floors and roof slabs were 2-in. concrete carried on bar joists which were welded in place. Lateral bracing of joists was by two ⅝-in. rods laid across and back welded to the bottoms of the joists.

Across the store fronts two sections of the new Bethlehem 36-in. girder beam was used, the sections being welded into a continuous beam after erection.

COMMITTEE ON HEAT TRANSMISSION of the National Research Council, 40 West 40th St., New York, of which W. H. Carrier is chairman, has recently issued its quarterly progress report for the quarter ending October 31, 1928. Various activities of the committee are noted, such as the work of the committee on nomenclature and definitions; report of the test code committee on building and low temperature insulation, preparation of texts on heat transmission by Professor McAdams and on insulation by Mr. McMillan.

TEXAS-LOUISIANA POWER CO., Fort Worth, Texas, has been acquired by the General Water Works & Electric Corp., formerly known as the General Waterworks Corp., which will take over the properties at once.



Electricity---What It Is and How It Acts*

PART XV. FACTORS INVOLVED IN HUMAN PERCEPTION. THE MEANING OF THE BROWNIAN MOTION. ACTION OF ELECTRONS IN VACUUM TUBES. DETERMINATION OF THE MASS OF THE ELECTRON

THERE HAS BEEN much argument and many tomes have been written upon the ability of the human mind, aided by the five senses, to understand the true nature of things. When we look at a chair, for instance, is the chair really there or does the chair merely exist in our mind? Certainly, the chair we see in a dream is just as real as the one we see when we are awake. Of course, we can go over and touch the chair—feel it and thus we say we prove that the chair is there, but do we? How do we know that our sense of touch is not in league with our sense of sight to deceive us? When we see a chair, our eyes do not come in contact with the chair itself—all that really happens is that light waves (or particles, if you are a modernist in physics) of certain frequencies enter our eyes in a certain pattern which our brain, from experience, interprets as a chair. Cut off the source of illumination and the chair vanishes, until we walk in its direction and stumble over it. When this happens all the metaphysicians and philosophers in the universe, as a rule, could not convince us that the chair was not there.

EXISTENCE AND PERCEPTION

Most of us, particularly when not engaged in philosophical thought, are pretty firm believers in our senses. When we can see a thing, we are fairly certain that something actually exists although we may have an entirely wrong idea as to what it is that we are looking at. Even when things are far away, we are likely to believe in their existence. And this is where the physicist who is dealing with atoms and electrons is at a great disadvantage, for he cannot show you the things he is working with and talking about. When the astronomer tells you he has just succeeded in measuring the diameter of a giant star in the constellation of Orion, you may doubt the validity of his measurement but when he takes you up on the roof and points out the star, you will have no doubts as to whether the star exists or not.

With the atomic physicist, things are different. When he tells you that he has just measured the diameter of the hydrogen atom, he cannot, like the astronomer, take you over to his microscope and show you the hydrogen atom. Here you may doubt not only his assertion that he has measured the atom but you doubt the very existence of the atom itself.

So when we talk glibly of atoms and electrons, what, after all, have we to prove that they really exist? In the articles that have preceded this, we have described them, their behavior, and have applied the principles of their behavior to an explanation of certain well-known properties of electric circuits. We have built up a theory of the structure of matter, showing how the electrons combined form atoms and how atoms combined form molecules. This theory is perfectly logical and agrees with known laws of physics, chemistry and electricity yet we admit that no one has ever seen a molecule, much less an atom or an electron. Then how do we know they exist?

PHYSICAL FACTORS IN PERCEPTION

Difficult as it is to answer this question, it is probable that we know as definitely that the electron exists as we do the chair referred to above. In either case, we are dependent upon the effect produced by the object upon certain other things which affect our senses. As explained above, when we see a chair we are merely conscious of a definite pattern produced on the retina of our eyes by electromagnetic radiation reflected from an object which we call a chair. The same is true when we look at a star in the heavens. The star we look at tonight may have been destroyed as the result of some cosmic collision, ten thousand years ago, yet we ordinarily would not argue with the astronomer as to whether it exists or not. We see it, therefore we think it exists. As a matter of fact, all that actually happens is that the light which left the star say one hundred thousand years ago is entering our eyes giving us the impression of a star.

Now an electron or an atom is entirely too small to reflect light, so there can be no hope that we can be made aware of its existence in the manner that a chair does. An electron or an atom, however, is endowed with energy which usually manifests itself as motion—extremely rapid motion. Suppose then that an atom or electron, moving at high speed, could collide with a much larger particle, say in the manner of a swiftly moving golf ball striking a football. It is evident that, in the latter instance, the energy of the golf ball would be imparted to the football causing it to move. Simi-

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larly, in the case of the atom and a large particle colliding, the large particle would be set in motion, indicating to us the presence of the atom. This, in fact, is just what actually occurs under certain conditions.

The Brownian Motion

Just about one hundred years ago, in 1827, to be exact, an English botanist by the name of Robert Brown[1] noticed a peculiar wiggling motion in a drop of liquid which he was observing under his microscope. This wiggling, he first thought, was due to life, that is, the wiggling of microbes, but when he repeated the experiment with "dead" matter, the same motion was observed. Although this phenomenon was studied by numerous observers and became known as the Brownian movement, it remained unexplained for 50 yr.

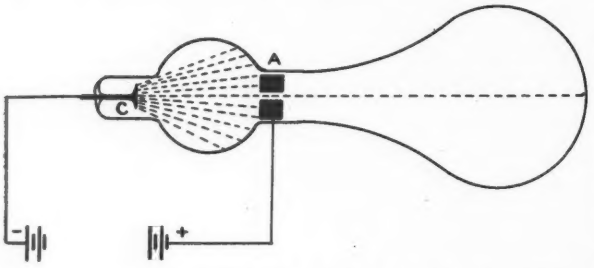


FIG. 1. DIAGRAM SHOWING THE PRINCIPLE OF THE CATHODE RAY TUBE

When a high potential is applied by means of a battery to the cathode C and a circular anode A placed in a tube from which most of the atmosphere has been exhausted, the few remaining molecules of gas in the tube will be ionized. The positive ions being attracted to the cathode strike it with such force as to liberate electrons which are immediately repelled from the cathode. Some of these electrons which are directed in the direction of the anode, pass through it, producing a cathode ray or electron stream in the space beyond the anode.

In 1880, however, Carbonelle, a Belgian investigator, in a paper published by his collaborator, Thirion, made the suggestion that the Brownian movements might be due to the continual bombardment to which the particles in the liquid are subjected because of the thermal agitation of the molecules of the liquid. This question of thermal agitation, it will be recalled, was discussed in a previous article.[2] Carbonelle's suggestion immediately set other investigators at work and in 1881 Bodoszewski, in studying the Brownian movements of smoke particles in air, saw in them an approximate image of the movements of the gas molecules as demanded by the kinetic theory of gas. Subsequently, due to the brilliant work of Einstein in 1905, this idea was subjected to quantitative test and proved correct.

This Brownian movement is a marvelous phenomenon to observe under a microscope, for in those myriads of dancing particles we are seeing the consequence of actual collisions between molecules and larger particles. In the Brownian movement, then, while we are not actually observing the atoms or molecules, we are observing their direct individual effect upon particles we can see.

Now it is this type of investigation that must be pursued in any investigation of the atom and the electron; we must permit the electron to do something which will act upon our senses. In the Brownian movement, the atoms and molecules act upon the particles in suspension but in trying to observe the effects of the electron in this manner, the method fails because of the extremely small size of the electron.

Fortunately, if the electron lacks the mass possessed by the molecule, it has something or can be given something that will reveal its presence and that is velocity. As long as the electron remained comparatively stationary as it is in ordinary matter (ignoring here its rotational velocity) we knew little about it but once it was endowed with high velocities in the vacuum tube it began to tell its story.

The Cathode Ray

In Fig. 1 is shown a diagram of what is known as a cathode ray tube. This consists of a cathode or negative plate C and a tubular anode or positive ring A enclosed in a tube from which most of the air has been exhausted. If a comparatively high voltage is applied to these two terminals as shown, a number of the gas molecules still remaining in the tube may be ionized as explained in a previous article[3] and the positive ions will be drawn to the negative plate with a velocity dependent upon the potential gradient of the field. If this is sufficiently high, the positive ions will strike the plate with such force that an electron will be jarred loose so to speak from the plate. Repelled by the negative plate from which they are derived, these electrons shoot off into space. Their energy is given to them by the battery which keeps the cathode negative by forcing on it electrons far in excess of its capacity for getting rid of them.

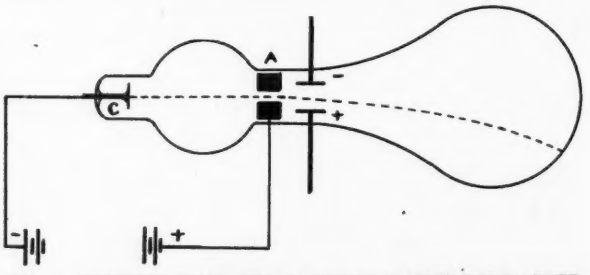


FIG. 2. SHOWING HOW THE CATHODE RAY IS DEFLECTED BY MEANS OF ELECTRICALLY CHARGED PLATES

As these electrons are shot off into space, they travel towards the walls of the glass tube. Many of them travel straight towards the anode. If the latter is made hollow as in the diagram, the tremendous velocities of the electrons will carry them straight through it, the attracting properties of the positive terminal having little or no effect on them. As a consequence there will be a stream of electrons in the space beyond the anode which can be used for experimental purposes.

This stream of electrons is, of course, invisible, but at the point where it strikes the glass walls of the tube it will cause the glass to phosphoresce, or if a chemically coated screen is placed at the end of the tube, it will phosphoresce brilliantly. By this arrangement the presence of the electron is revealed to the eye.

Suppose that, in addition to the cathode and anode in the tube, we arrange just beyond the hollow anode a set of plates as shown in Fig. 2 which can be charged positively or negatively by another battery. It will be

[1] Philosophical Magazine, IV (1826), p. 161.
[2] Part V, July 15, 1928, issue, p. 778.
[3] Part VI, August 1, 1928, issue, p. 828.

recalled from our discussion of the conduction of electricity through gases, that when an electron is placed in an electric field, it will be acted upon by the field and will be drawn toward the positive terminal. It will be evident, therefore, that if a charge is applied to this new set of terminals in the cathode ray tube while the stream of electrons is passing between them, the electrons will be attracted to the positive plate and the stream as a whole will be deflected as shown. If the charges are reversed the deflection will be upward; if the charge is reduced or increased, the deflection will be reduced or increased.

In other words, by varying the electrical charge on the plates the direction of the stream of electrons can be changed at will. It is much the same action as

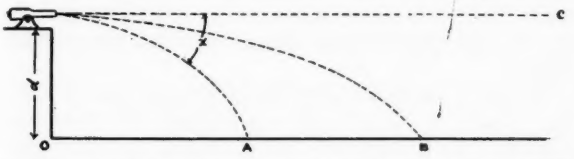


FIG. 3. DIAGRAM ILLUSTRATING THE ACTION OF GRAVITY AND SPEED UPON THE TRAJECTORY OF A PROJECTILE

occurs when the nozzle of a hose carrying a stream of water is moved back and forth—a slight movement of the nozzle causes a wide movement of the stream.

Also the cathode ray can be deflected by placing the tube between the poles of a magnet.

Determining the Velocity of the Electron in the Cathode Ray Tube

J. J. Thomson made use of both of these methods in determining the velocity of the particles. The method he used consisted in permitting both an electric field and a magnetic field to act upon the ray at the same time and arranging the respective fields in such a manner that one would counteract the other. In other words, the effect of the electrostatic field which, say, deflected the ray upward was counteracted by a magnetic field which tended to deflect the ray downward. By properly proportioning the field strengths an exact balance between the forces was obtained and the ray would suffer no deflection.

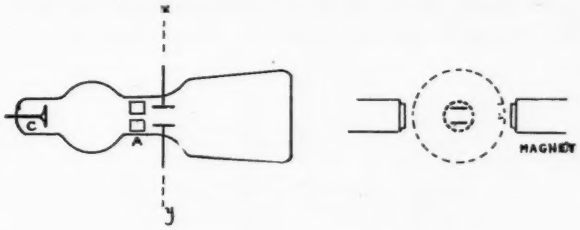
Now it so happens that the ratio of these intensities depends only upon the velocity with which the particles are moving. The principle involved is the same as that which governs the trajectory of a projectile fired horizontally at some distance above the surface of the earth. If there were no gravitational attraction, a projectile would travel out horizontally when fired from the gun in Fig. 3. With the force of gravity acting upon the projectile from the instant it leaves the gun, it will be gradually pulled to earth and the trajectory instead of being a horizontal will take the form of a parabolic curve as shown at A for instance. Now the point at which the projectile strikes the earth, assuming a constant gravitational acceleration, is purely dependent upon the speed. If it leaves the gun with a certain speed, it will strike the ground at A. If the speed is increased, it will come down at, say, B. The time elapsed between the time the bullet leaves the gun and the instant it hits the ground is a constant regardless of the horizontal distance of travel.

Knowing the force required to deflect the trajectory of the projectile through a certain angle, the speed can be calculated.

These same principles hold in the case of the cathode ray and it was by a series of experiments based on this principle that J. J. Thomson determined the speed of the particles in the cathode ray. Thomson's equipment is shown in Fig. 4.

Thomson's Experiments in Determining the Mass of the Electron

Thomson next sought to measure the electric charge of the cathode ray particles but at that time it was not known how to measure this quantity directly, so he devised a method which gave the ratio of the charge on the particle to its mass. This was simple and was accomplished by merely using the electric charge to deflect the cathode particles. It is evident from a study of Fig. 3 that the acceleration to earth of the projectile



A B

FIG. 4. THOMSON'S APPARATUS FOR DETERMINING THE RATIO OF THE CHARGE OF THE ELECTRON TO ITS MASS

A is a side view of the cathode ray tube showing the plate electrodes for deflecting the cathode ray by the electrostatic field. At B is shown a section through x-y showing the magnets for causing the deflection by the magnetic field.

is dependent upon the force of gravity, but that the horizontal distance it travels is dependent upon the mass of the particle.

Similarly with the cathode particles, the downward deflection depends upon the applied charge to the plates but the resistance to deflection depends upon the mass.

Thomson found that this ratio of the charge of a cathode particle or electron to its mass was just about 1700 times the similar ratio for the hydrogen ion in electrolytic conduction.

Assuming that the mass of the hydrogen ion[4] is essentially the same as that of the hydrogen atom, and that the charge on the cathode particle or electron is the same as that usually associated with the hydrogen ion, Thomson was forced to the astonishing conclusion that the mass of the electron was about one seventeen hundredth of the mass of the hydrogen atom. A similar research with similar results was conducted independently by Wiechert.

Here, then, was the first experimental evidence and intimation of a particle very much smaller than the hydrogen atom. Once this much was known, there came the question: What is the value of the charge itself? The definite answer to this finally came from Professor Millikan of the University of Chicago. Millikan's work in evaluating the charge on the electron will stand for all time as among the most brilliant and far reaching in the history of mankind.

[4]The hydrogen ion, is the nucleus of the hydrogen atom. See discussion of Ions, p. 880, August 15, 1928 issue.

Reactive Component in A. C. Circuits

PART X. USE OF SYNCHRONOUS AND STATIC CONDENSERS IN POWER FACTOR CORRECTION. BY V. E. JOHNSON

IN THE PREVIOUS article* we discussed several types of corrective apparatus for power factor correction, among which was included the synchronous motor. In this article we will continue this subject with a discussion of synchronous condensers.

Synchronous condensers differ from synchronous motors only in that they have no provision made for belting or coupling to any mechanical load and are designed to carry their rated kilovolt-ampere load at zero power factor leading. Though lagging corrective kv.a. is seldom needed in the case of long lightly loaded transmission lines, it is of interest to note that at zero lagging power factor, the rating is reduced to about 50 per cent, this corresponding approximately zero excitation.

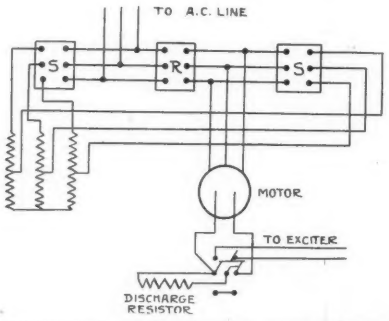


FIG. 1. STARTING CONNECTIONS FOR SYNCHRONOUS MOTOR

Comparative characteristics of static and synchronous condensers have been given and from them it is evident that there is no distinct line of cleavage between what constitutes a good application for one and for the other. The synchronous machine is, however, supreme in the field of bulk correction such as that required in large industrial plants, and at the main substations of central stations. In the large ratings required in such cases, the static type is economically impossible.

VOLTAGE REGULATION BY MEANS OF PHASE MODIFIERS

In a previous chapter, the effect of leading and lagging currents on the regulation of transmission lines was discussed. This phenomenon permits the use of synchronous phase modifiers for purposes of voltage regulation. The range of voltage variation possible by this means is determined by the inductance of the lines but ordinarily it is possible to obtain commercially satisfactory operation.

The method of controlling the voltage by synchronous motors is exactly equivalent to that which would be used if the machine operated as a mechanically driven generator. Increasing or decreasing the excitation has a corresponding effect on the lines to which the machine is connected.

Aside from the meters and instruments necessary for the intelligent operation of a synchronous machine, the control apparatus is essentially that used for starting and for field adjustment, therefore it is a combination of that used for induction motors of the squirrel cage type and that used for alternating current generators. The starting torque of a synchronous motor is due to the interaction of the stator flux and the currents induced in the field structure. During the period of acceleration, high voltages are set up in the rotor windings and these may assume destructive proportions unless limited in some manner such as, for example, the use of a discharge resistor connected across the collector rings.

Figure 1 shows the elementary connections for starting, using three 3-pole oil switches and an auto-transformer. The excitation is taken from a bus, through a switch equipped with discharge contacts. The starting switches energize the auto-transformer windings and connect the low voltage taps to the motor terminals. Interlocks are provided, which make it impossible to close the running switch, until the starting switches are opened.

MEANS FOR AUTOMATIC STARTING

Automatic starting is accomplished by using electrically operated switches, controlled by relays arranged in various sequences. The proper condition for changing to the running switch is determined in several different ways, the relay functioning upon a decrease in the stator or rotor current, or an increase in the exciter voltage. The master relay which initiates the series of operations, may be closed by a push button, by a clock, by remote control from some other station, or by predetermined voltage conditions.

Motors operated without any attendant have numerous protective features and are ordinarily arranged to clear themselves from the line if the temperature of the stator, rotor, or bearings becomes excessive, or if there are internal failures in the windings. The introduction of automatically controlled synchronous phase modifiers permits the correction of power factor at points where a manually operated machine would be undesirable and justifies installations that previously would have been uneconomical, due to the cost of attendance.

While the exciting current taken by synchronous condensers may be controlled by ordinary hand operated exciter and field rheostats, for installations of any importance, it is preferable to install automatic regulators. These may be of the familiar vibrating type which operate on the exciter field, or of the rheostatic type connected in the condenser rotor circuit, the latter being somewhat less complicated.

STATIC CONDENSERS

Theoretically and actually a static condenser is the most direct means of supplying a leading reactive component for the purpose of power factor correction. Its phase characteristics have already been discussed in

*Oct. 15, 1928, p. 1091.

considerable detail but a simple analogy will give a clearer conception of the interchange of current which is the basis for its corrective action.

Figure 2 is an elementary steam engine having the piston P and the steam ports S^1 and S^2. Live steam has entered the port S^1 until the moment of "cutoff," and has caused the piston to move in the direction to the right. The exhaust is forced out through the opening at S^2 but when the piston passes this port, a quantity of steam will be imprisoned in the space indicated by the shading. The resulting compression will absorb the energy of the piston, stop it entirely and then start it upon the return stroke. During a small portion of the stroke, the piston is thus storing up energy which is later to be returned to it and for that interval the piston and the imprisoned steam constitute a small closed system in which energy is being interchanged but none received from the outside.

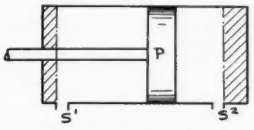


FIG. 2. STEAM ENGINE ANALOGY FOR EXPLAINING POWER FACTOR

To carry the analogy further, it may be assumed that due to a constricted exhaust opening, the dead steam begins to absorb the energy of the piston momentum early in the stroke, so that any moment the forces acting in the cylinder are two-fold: first—the live steam forcing the piston in the direction indicated by the arrow and so doing useful external work; second—the exhaust steam absorbing the energy of the piston and preparing to return it on the return stroke.

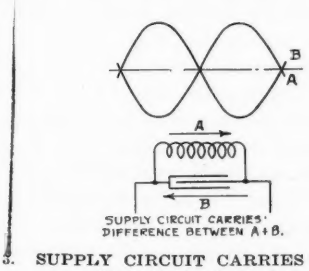


FIG. 3. SUPPLY CIRCUIT CARRIES DIFFERENCE BETWEEN A AND B

These two forces may be considered as the power and wattless components of the total cylinder energy transformation, the former doing useful external work, while the latter (though none the less essential to the successful operation of the engine) remains inside.

This analogy, while somewhat crude, is interesting in that it gives a mechanical definition of power factor that represents fairly accurately the conditions in an electrical circuit in which capacity and inductance are balanced against each other.

Figure 3 shows such a circuit, with curves and arrows to indicate the phase relations, and instantaneous relative direction of current flow through the two parallel paths. If the magnetizing and charging currents are equal, they will be confined to the closed loop and will not reach the generator at all. If they are not equal, the difference will flow through the supply circuit.

Construction of Static Condensers

Essentially a static condenser consists of two conducting elements separated by a suitable dielectric material. An elementary form of it is the Leyden jar, shown in Fig. 4. Economy of space and material is obtained by an assembly of alternate sheets of metal foil and insulating paper, as shown schematically in Fig. 5. The amount of energy that can be stored in such a condenser is determined by the area of the conducting elements, by the nature of the dielectric and by the voltage stress. For a given volume and material, the kilovolt-ampere capacity varies as the square of the voltage stress—this must accordingly be kept as high as possible in the interest of economy of manufacture.

In their commercial form, static condensers consist of alternate sheets of foil and paper, stacked and connected as in Fig. 5 and then assembled in metal tanks of convenient size. These tanks are filled with insulating material, such as transformer oil, and hermetically sealed.

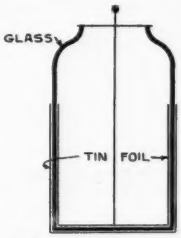


FIG. 4. LEYDEN JAR, A SIMPLE TYPE OF STATIC CONDENSER

Commercially, a complete assembly consists of the required number of such units connected in suitable racks or frames and equipped with a control switch for disconnecting from the line. There are several schemes of connection, determined by the voltage and current capacity, a common one being that in Fig. 6. Potential transformers or discharge resistors are connected across the condenser terminals in order to dissipate the charge when it is removed from service; otherwise this would be retained for a long time and result in injury to anybody coming in contact with the terminals.

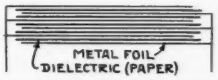


FIG. 5. ELEMENTS OF A CONDENSER

While it is not possible to change the corrective capacity to meet rapidly changing conditions, this is ordinarily not necessary. It is entirely practical to disconnect any number of units to compensate for major changes in load conditions. This is generally done by removing the connecting straps from the unit terminals, but in special cases auxiliary oil switches are used to disconnect certain groups of units.

Voltage Standards

The economy of material which results from the use of high voltage stresses in condensers has led to an attempt to standardize on units having a minimum rating of 2300 and the use of step up transformers for

application to lines of lower voltage. Figure 7 shows the connection of capacitors with transformers so arranged. There are, however, available low voltage units for use on 220, 440 and 550 v. feeders, and for the individual correction of motors at their terminals. In any, except the very smallest sizes, there is a price differential in favor of the high voltage units with

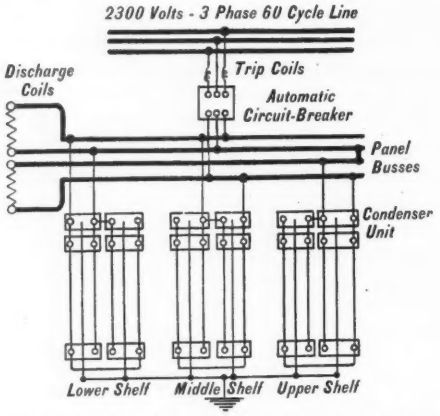


FIG. 6. CONNECTIONS OF A 2300-V. CONDENSER WITHOUT TRANSFORMERS

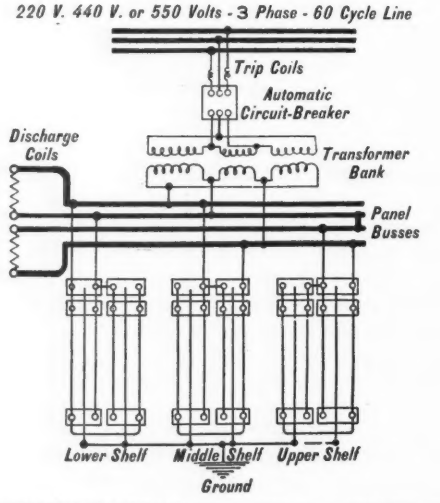


FIG. 7. WIRING DIAGRAM OF A 2300-V., 3-PHASE, STATIC CONDENSER EQUIPMENT USING TRANSFORMERS

transformers as is shown in the following tabulation of approximate prices:

Kv-a. Capacity	Low Voltage Units 440 v.	2300 V. Units Including Transformers 440 v.
30	$1400.00	$1150.00
60	$2300.00	$1900.00
150	$4600.00	$3700.00

The higher cost will in some cases be offset by the saving in copper incident to removing from the feeders the burden of the wattless current and also by the saving in transformer losses, which are 2 per cent to 3 per cent as against 5 per cent for the condenser.

SLAG ON BOILER tubes may be prevented by extensive water cooling in the upper portion of the furnace and by the use of slag screens in the boiler itself.

Working on Live Electrical Circuits

BY MARIN PHILLIPS

WHEN WORK has to be done on panel boxes, cabinets, switches, buses, etc., shut the current off if possible so that the work can be accomplished in safety without taking any undue risks. Of course, there are times when the current can not be shut off, which makes it necessary to work on the circuit alive. In most cases this can be carried out in comparative safety if the proper precautions are taken to guard against the accidents that can happen due to a short circuit.

Whenever the work consists of splicing or tapping in a new dead line onto a live one, never fail to test the insulation resistance between wires and to ground. This will be necessary to guard the possibility of attempting to splice on a line that is short circuited or grounded. The Megger testing set or the ordinary magneto tester that will ring through 25,000 ohms resistance will be exceedingly useful when such tests are made. When splices are to be made on live cable work, it is a safe precaution to cut the insulation away only where the tap is to be made and from one cable at a time. Splice on one wire and tape up the joint securely before cutting away the insulation on another cable for the next splice. It is a good safety precaution to have along a short piece of 10-amp. fuse wire which can be touched between the live cable and the dead one that is being tapped on to it. In case there is a fault in the line that was not discovered in the first test, this small fuse wire can blow without doing any damage whereas, if an attempt is made to splice the cables together, it is a possibility that great damage can be done. On the other hand, the workman attempting to make the splice may be severely burned or be caused to fall, inflicting an accident more or less serious in nature.

Whenever it is necessary to do work on live buses and switches, all of the phases should be well protected with guards. This protection is best accomplished by covering them securely with rubber blankets, empire cloth, fiber boards, etc., or by constructing boxes out of dry boards deep enough to cover the width of the bus well and wide enough to slip over the bus. When work is being done on live buses, it is safer and better to work from underneath rather than above if possible. If anything should happen, causing a flash, the arc and heat will travel upwards, which is almost sure to catch the workman in the face, increasing the possibility of serious burns. Another advantage of being underneath and reaching up to the work rather than sitting on it and reaching down to accomplish the work as in general practice is in case of a shock or a flash the workman will have a better chance to escape by being able to get away faster.

DALLAS POWER AND LIGHT CO., Dallas, Texas, has authorized an expansion program to cost about $3,000,000. Included in this work will be an extension to the electric generating station at Dallas to increase the capacity about 50 per cent. A 25,000-kw. generating unit, with the necessary boilers and auxiliaries, will be installed.

Repairs Made on the Job Save Time and Money

AS INDICATED in the editorial on Repairs in the Plant, which appeared on page 1014 of the Sept. 15 issue, I believe it is exceedingly important that operating engineers have some shop training so as to enable them to make repairs of their own equipment.

In one case, the two water wheels installed became badly worn. Since they had been built a long time ago, the builder no longer made parts for these machines, preferring to sell new machines, although the wheels in question were in such a condition that they could still run for a long time.

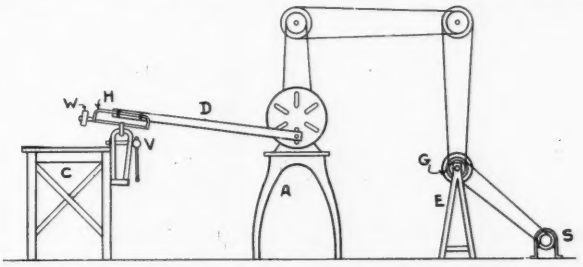
Local machine shops did not desire the work and as the steam plant was not running, the power plant crew and two machinists prepared to make the repair. Several pieces of 1¼ by 4½-in. iron had to be cut in lengths of 2 ft. and drilled with 1½-in. holes at each end. We had no power hack saw; power had been cut off and it required about one day for a mechanic to saw off three pieces by hand.

To speed this process, the engineer assembled an old lathe A, shown in illustration, connected a large portable electric drill to the electric circuit, fastened a small pulley in a chuck and clamped the drill to the floor as shown at S. One of the emery wheels was removed from the grinder E and another pulley put on this spindle at G. This not only reduced the speed of the lathe but also made it possible to use a small high-speed motor as a drive. The large emergy wheel on the other end of the spindle acted as a flywheel. A 2-in. belt connected the drill, motor and grinder and a piece of flooring, D, ¾ by 3½ in. by 6 ft. long, was used as a connecting rod. One end of this was fastened to the face plate which was attached to the lathe and the hack saw was attached to the other end at H. A guide was made by fastening a slotted piece of board to the edge of the bench C and the hack saw on the iron bar and the vise V. A weight W was placed on the handle of the hack saw to make it cut better.

With this arrangement, the operator could simply set the saw, start the motor and, when the bar was cut through, stop the lathe and reset the bar for a new cut. In the meantime, this man could thread a number of 1¼-in. bolts and do other machine work. This emergency hack saw did more than twice as much work as had been formerly done by hand in the same time.

In another instance, a small portable engine was connected with a boring bar and an engine cylinder bored out in place. Otherwise, such a cylinder would have had to be taken to a distant shop at a considerable expense.

A short time ago, it was necessary to turn up a booster commutator. To dismantle the booster and remove the armature, in order to send it away for repair, would have required much time. A portable turning device operated by a small motor was secured and connected onto our switchboard. The booster was cut out of service in the morning and by 10:30 a. m. was ready



IMPROVISED POWER DRIVEN HACKSAW MADE UP OF AVAILABLE MACHINE PARTS, REDUCES TIME AND COST OF CUTTING OFF LENGTHS OF STEEL BAR

for machining. The chief and watch engineer took turns and at about 6 p. m. the booster was in service again. If it had been sent to an outside shop, it would have been out of operation for four or five days.

Portable devices, such as portable keyway cutters are now on the market that greatly facilitate making repairs. Portable air drills and electric drills are obtainable that may be easily attached to lathes, shapers or drill presses to furnish power for operation.

When a plant is supplied with such tools, men take a special interest in using them and, therefore, in keeping their power equipment in good operating condition. Unskilled labor, in such plants, soon learn to make creditable repairs and become good mechanics. The time and expense thus saved, as well as the greater interest the men have in their work, result in added worth to their employers.

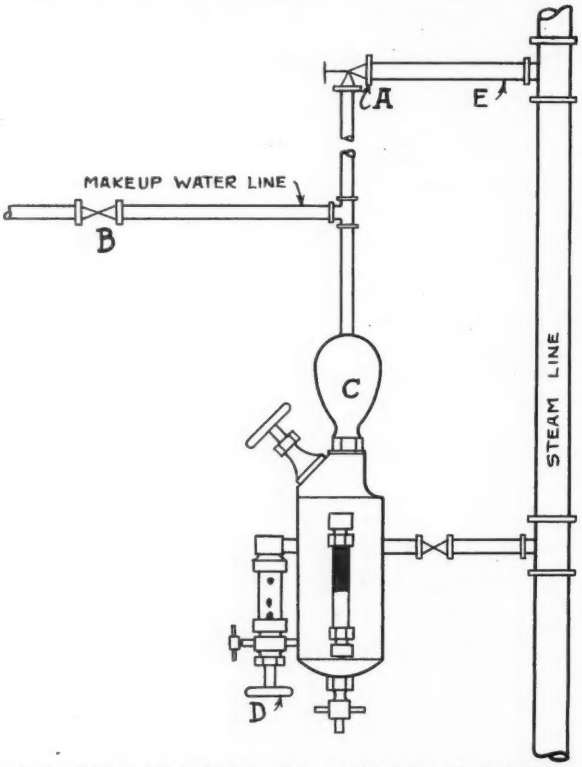
Cambridge, Mass. R. A. CULTRA.

Hydrostatic Lubricators

CONSIDERABLE TROUBLE is often encountered with the use of the hydrostatic lubricator in regard to the condenser becoming hot and failing to condense the steam, thereby interfering with the operation of the lubricator.

Cooling the condenser is usually accomplished by pouring water over it or soaking some waste in a pail of water and laying it around the condenser, repeating this procedure until it becomes sufficiently cool to condense the steam. This is a slow method; also it makes a sloppy mess around the lubricator and on the floor, because considerable water is used to cool it.

This can be accomplished much quicker and easier as shown by the accompanying sketch. A ¼-in. line for



CONNECTION FOR REFILLING CONDENSER PROVIDES METHOD FOR COOLING HYDROSTATIC LUBRICATOR

make-up water is connected to the lubricator as shown. When the condenser becomes hot and fails to work close valve A and also valve D and open valve B. The condenser will immediately become filled with water and cool off at the same time.

Care must be taken that valves A and D are closed before opening the make-up water line because, if the make-up water pressure is higher than the steam pressure, the water will enter the steam line through pipe E and it is obvious what would happen, if the lubricator was attached to an engine. Be sure to close valve B before putting lubricator into operation.

Oxford, Mass. LORNE B. STRADER.

Boiler Baffle Problems

PLASTIC REFRACTORY has certain advantages over metal for boiler baffle walls, such as that it may be molded without difficulty to meet any boiler tube shape. Thus, if bent tubes are used, it is unnecessary to do any forced fitting, as is the case where metal baffles are used. The principal difficulty experienced with plastic material alone, is that, unless provided with expansion joints, the baffle will surely crack and gas leakage with its attendant reduction in boiler efficiency, will result.

Many attempts have been and are still being made to produce a refractory material that will not crack but all such attempts have failed. It is believed by some engineers that this can be accomplished, if the refractory has the same coefficient of expansion as the steel contained in the boiler tubes. According to the Engineering Experiment Station of the University of Illinois, the coefficient of expansion of refractories is variable. But, even if refractories did have the same coefficient of expansion as the steel tubes, the problem would still remain unsolved.

This boiler baffle problem is not merely one of coefficient of local expansion. The boiler baffle must be capable of adjusting itself to differences in boiler length. The boiler at its top may expand more than it does at the bottom. The tubes facing the fire are subjected to the highest temperature, consequently they expand more than the tubes farther away. Hence a boiler baffle, cutting through tubes that have a variable expansion, must be able to meet that variable expansion. This cannot be done by the use of a refractory material that has the same coefficient of expansion as the boiler tube material. The temperature at the points of intersection of the baffle and tubes may be constant, yet at the same time the baffle may be called upon to take care of considerable adjustment. The problem is therefore not one of temperature.

Production of a refractory material that stretches and compresses like rubber or like a corrugated metal expansion joint has also been attempted. But this has been unsuccessful. In one respect, the behavior of refractories is much like that of cast iron; they are strong in resisting compression but weak in resisting tension. In fact, engineers always assume that they have no tensile strength whatever.

Some engineers erroneously believe that boiler baffles must be capable of resisting exceedingly high temperatures. Baffles do not receive the direct heat, as do boiler walls. Baffles are usually protected by the comparatively cool boiler tubes, consequently there is seldom danger of burning. Thin metals may be used in the baffle, if desired, but the metal must not be put there for the purpose of reinforcing the baffle. Reinforcing metal should never be used in any baffle that will be subjected to the variable adjustment stresses that are so common to most water-tube boilers. Rigidity is not the solution; flexibility should be sought.

Newark, N. J. W. F. SCHAPHORST.

Cleanliness and English Aid in Advancement

AS A GENERAL RULE, just how does that part of the public with which we come in contact regard us engineers? By regarding, I mean the measure taken of us from a civic and moral standpoint. Ours is not a business that plays at all to the grandstand. It is not given front page publicity when one of its followers blazes the trail in some new kind of service. Instead, it is a business of which little public notice is taken. Comparatively few realize its importance to a community until the lights go out or the wheels stop turning.

Some of our work requires the wearing of overalls and jumper but that should in no way lower the standing or character of the man who wears them. I believe

it does not. The worthwhile man can clothe himself in working togs consistent with the situation he has to handle but that in no way reduces his caliber as a man, if his aim is to be of service to his employer and fellowmen. That feeling from the inside, if present, will radiate out regardless of how much dust, oil or ash the man may collect temporarily on the outside. This same worthwhile fellow is the one who also clothes himself properly when he is called upon to meet those whose work demands business dress and unsoiled hands. His worth as a citizen is of equal importance with that of the one whose work is more before the public and his judgment and opinions are no less valuable.

A few years ago, I worked under a chief engineer of a large company in the east who had followed such advice as Mr. Brown in his article on page 1108 of the October 15 issue has given. His daily appearance in the plant and shops was neat and trim and every part of his plant was also neat and clean. He was equally at home with the men under him and with the higher officials of the company. Both groups respected him highly. During a conversation, he told me that he had formed the opinion that the general public considered operating engineers to be a "poor lot." His belief was they were not and that the best proof was to give convincing evidence to the contrary.

Another instance, not so elevating, was that of an employe of a neighboring station, who, in visiting our plant one day said of another engineer that he was "a regular engineer too, just like the old man, swears as he does, and his pet by-word is ———." Which of these fellows measures up the better as representing a profession so important to the public and which really is the more value to the public as a engineer-citizen? Which will eventually reach the higher positions of trust and responsibility and with it the more responsible position of linking his engineering service with other business? The answer is not hard to find. Those in authority know that the qualifications needed to fill the big positions include refinement and good English as well as good judgment.

It so happens that I have worked for both of these chief engineers. Regarding the first mentioned, my memories recalling the daily visit and chat concerning our business are most pleasant. His open mind was ready to receive, in fact was waiting for, ideas that, if at all usable, were given opportunity. His hobby and ours were talked over and the general atmosphere of fellowship and kindliness permeated the entire force.

Of the second, my memories are not so pleasant. Visits were made only when necessity required them. No freedom of fellowship prevailed. In its place was a feeling of "He's boss and will carry his will because he is." Much of the English he spoke wasn't good, consequently it wasn't effective as a tool of persuasion and encouragement. Our ideas, when we got them over, had little weight and our hobbies little regard from him.

Some, who would be no lifting power to any profession, have chosen engineering as theirs. But the majority know when and how to use good English appreciate unsoiled brains and hands and know how to use them, and have an understanding of their fellowmen and their professions.

Keyport, N. J. GEO. B. LONGSTREET.

Pump Gland Water Drip Aids Operation

REFFERING TO THE ARTICLE by Charles Mehr on Lubrication Reduces Wear on Packing, published on page 949 of the Sept. 1 issue, I believe his trouble was caused by the stopping up of the water-seal pipes.

Packing glands on centrifugal pumps should never be drawn up so tight that they heat and dry out in a short time. The packing gland is water sealed and, if it is tightened just so that water drips slowly from the gland, hardening of the packing, provided it is a good grade of flax packing, will be prevented. If a high vacuum is carried, it is necessary to tighten the gland more than otherwise, in which case it will become slightly warm.

In the plant in which I am employed, we have a centrifugal pump, running 1750 r.p.m. against a 150-ft. head. This operates, on an average, 22 hr. per day. The packing, which is of a good grade of flax, has been in for over a year but is still in good condition.

Cape May, N. J. HOWARD S. CHESTER.

Erosion Caused by Jet of Steam

EROSIVE ACTION of a steam jet when impinging on metal may be very destructive. A small jet of escaping steam has a surprising ability to cut and wear away metal. Valve stems and spindles are not infrequently

IMPINGING JET OF STEAM WEARS HOLE THROUGH VALVE STEM

found which have been cut in two, or worn down to string-like proportions, by its slow abrasive action.

Somewhat freakish is the result of steam action shown in the illustration. In addition to cutting away the circumference of the guide spindle or stem symmetrically, the job was given a touch of the artistic by cutting a neat hole through the center at the same time, with apparently the same attention to proportion a sculptor would give the two hands of a human figure.

Missouri Valley, Iowa. FRANK BENTLEY.

KNOWLEDGE is an excellent drug; but no drug has virtue enough to preserve itself from corruption and decay, if the vessel be tainted and impure wherein it is put to keep.—Montaigne.

Editorial Comment

Step on It

As an experienced automobile tourist approaches an important city on his route, he begins checking up on the condition of his car with the intention of putting it in first-class condition for the next few hundred miles stretch in his tour. Gasoline, oil and water receive his first attention. Tires and mechanical adjustments, such as brakes, valves and carbureter, will be given some thought and if anything about the car needs replacement or a mechanic's services, the car goes to a garage. Then, before leaving the city, the tourist gets the latest word on the condition of the roads, decides on his next objective, estimates the time it will take and starts with confidence that he will reach his destination as planned.

Each year as the first of January approaches business firms begin closing up the books of the year and opening others for the year to come. Like the tourist, the business man may have found defects in his business system which need correction but no doubt the things that concern him most are the unforeseen happenings of the future—How can he recognize the approach of changing conditions? What can he do to meet changes as, or even before, they occur?

In our study of conditions as they exist in the power plant field today, of development work now in progress and arranged for, of the attitude of mind which exists among men of affairs controlling the purse strings of industry, we are led to the conclusion that the coming year will see many new developments in the power plant field. The building of central stations will continue about as it has the past two or three years; many large industrial plants of prewar construction will undergo rehabilitation; hastily designed and built war time industrial power plants are going over to central station service; large modern industrial plants are going to be designed by engineering rather than catalog standards; several central heating plants are being planned.

Everything considered, the indications are that the coming year will see an increase in construction, a demand for the better class of power equipment and wider opportunities for power engineers who have kept themselves familiar with modern practice in the generation of power and its use in their particular fields.

The roads are good, the skies are clear, your car is in good order and we wish you the happiness that comes from attaining your desired destination.

Interconnection as a Factor in Continuous Service

Interconnection of electric power plants and systems has been progressing at an extraordinary rate in all parts of the country. Recently a remarkable example of the value of such interconnection took place in southeastern Kentucky.

After months of dry weather, a steady downpour started and continued until all the streams were flooded. The flood continued until the Cumberland River spread a half mile out of the banks at Pineville, flooding the entire business section. Five miles north of Pineville is located a 40,000-hp. generating station, the principal unit in the Kentucky Utilities southeastern Kentucky transmission system.

A 40-foot rise in the river in 72 hours brought the muddy, debris-laden water to 18 inches above the ground floor of the power plant. It was considered advisable to stop the plant to conserve coal and release the operating staff to fight the flood. Dix River Hydroelectric plant, 90 miles away, picked up the load supplied by Pineville.

Some time later the Pocket Stream Station, 50 miles east of Pineville in a mountain valley, was caught in the same position. There was no interruption of service in the mountain district, however, even when a large tree fell 125 feet down the mountain side upon a 33,000-v. transmission line. Service was switched instantly to other lines and repairs made without delay.

Although there is a limit to the distance that power can be transmitted commercially, the value of interconnection in emergencies cannot be overestimated. It is in effect insurance against the failure of supply, which may be caused by so many unforeseen conditions. Every flood piles up evidence of the value of this practice and adds to the existing fund of evidence showing the value of the power industry in national or local emergencies.

Customer Ownership

Public utility securities are steadily increasing in popularity and customer ownership is now a big factor in public utility financing. Recently, at the ground breaking ceremonies of the new James H. Reed station, A. W. Robertson, president of the Philadelphia Co., stated that:

"The money to build the plant must come from many different people. The investment in public utilities is so huge that they can never be financed out of earnings and the company must sell stocks and bonds . . . We will get the money from big and little investors the country over. If we get it, and we will, it will be for one reason and that reason is that those men and women who have saved money and want to invest it think it will be safe . . . If these potential investors did not think it would be safe with us, . . . we could not get one penny.

"This power plant is possible only because of mutual confidence which pervades the whole situation including investors, community and company . . . It will be seen that the management occupies a position of trusteeship in which it must be faithful and look after the interests of the consumers who depend upon it."

Mr. Robertson was, of course, speaking of a particular case, yet with a few exceptions it is true of the industry as a whole. The remarkable growth has been due primarily to the service rendered but, without the confidence of the public, the growth would have been much less rapid and less money for further construction have been forthcoming. The popularity of public utility

investments is evidence of the confidence the public has in the power industry.

Shocking Fish as a Hydro-Plant Aid

Shocking fish is not what one could consider even passably good sport, unless perchance the shocking happened to be done by means of a cleverly disguised hook.

In Oregon, however, shocking is resorted to by full grown engineers for the purpose of preventing the fish from committing suicide in hydraulic turbines. The shocking device is made up of two parallel electrodes, or rows of electrodes, suspended from a wooden framework. One set is near the surface of the water, the other near the bottom of the channel and when current is turned on an electric field is set up, the strength of the field, of course, decreasing as the distance from the electrodes is increased. A fish swimming into the edge of the field is usually turned back. If not, an increasingly severe shock is administered as the fish enters the field. It is said that a field current from three or four volts will discourage a 30-lb. salmon "but that the fish will not be harmed, even if it swims entirely through the field", all of which leads us to believe that some people believe too much in fairies and place too much confidence in the humanitarian instincts of a turbine runner.

Acknowledgment

In an issue of this character, that is, one devoted entirely to a treatment of a particular phase of power plant engineering, it is highly essential that the information presented be up to date. The handling and preparation of fuels is a subject as old, if not older, than the field of steam power engineering and it would be presumptuous on our part to devote an entire issue to the subject unless the information presented were of an up-to-date nature.

To make this possible naturally requires the coöperation of those actively engaged in the field, not only the operators—the actual handlers of fuel, but also the manufacturers who make the equipment. Fortunately, there are few secrets in the power plant field and the leaders of the industry have always been found willing to coöperate and to give to the profusion the results of their experience. It is because of this spirit of coöperation that the present issue of Power Plant Engineering has been made possible.

In many cases, direct credit is given to the sources from which data were secured but this has not been possible in all cases, particularly where details of manufacturers' equipment were involved. We take this opportunity, therefore, to acknowledge the assistance given us in the preparation of this issue to the following manufacturers of power plant equipment:

Allen & Billmyre Co., Inc., New York, N. Y.
Allen-Sherman-Hoff Co., Philadelphia, Pa.
American Pulverizer Co., St. Louis, Mo.
Anderson Engine & Foundry Co., Anderson, Ind.
Bailey Meter Co., Cleveland, Ohio.
Barber-Green Co., Aurora, Ill.
Bethlehem Steel Co., Bethlehem, Pa.
S. F. Bowser & Co., Fort Wayne, Ind.
B. G. Construction Co., Berne, Ind.
Blaw-Knox Co., Pittsburgh, Pa.
Brady Conveyors Corp., Chicago, Ill.
Buffalo Forge Co., Buffalo, N. Y.
Burt Mfg. Co., Akron, Ohio.
Chain Belt Co., Milwaukee, Wis.
C. J. Manufacturing Co., Philadelphia, Pa.
Combustion Engineering Corp., New York, N Y.
Economy Pumping Machinery Co,, Chicago, Ill.
Elliott Co., Jeannette, Pa.
Erie City Iron Works, Erie Pa.
Fairbanks, Morse & Co., Chicago, Ill.
Federal Pneumatic Systems, Inc., Chicago, Ill.
Foster Wheeler Corp., New York, N. Y.
Frederick Iron & Steel Co., Frederick, Md.
Freeman-Riff Co., Terre Haute, Ind.
Fuller Lehigh Co., Fullerton, Pa.
Furnace Engineering Co., New York, N. Y.
Gilbert & Barker Mfg. Co., Springfield, Mass.
Grindle Fuel Equipment Co., Harvey, Ill.
Griscom-Russell Co., New York, N. Y.
Guarantee Construction Co., New York, N. Y.
Hardinge Co., York, Pa.
C. W. Hunt Co., West New Brighton, N. Y.
Ingersoll-Rand Co., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Kennedy-Van Saun Mfg. & Eng. Corp., New York.
Link-Belt Co., Chicago, Ill.
Mead Morrison Mfg. Co., East Boston, Mass.
Metric Metal Works, Erie, Pa.
Orton Crane & Shovel Co., Chicago, Ill.
Peabody Engineering Co., New York, N. Y.
Pennsylvania Crusher Co., Philadelphia, Pa.
Richardson Scale Co., Clifton, N. J.
Riley Stoker Corp., Worcester, Mass.
Robins Conveying Belt Co., New York, N. Y.
P. H. & F. M. Roots Co., Connersville, Ind.
Ross Heater & Mfg. Co., Buffalo, N. Y.
Schutte & Koerting Co., Philadelphia, Pa.
Stearns Conveyor Co., Cleveland, Ohio.
Sauerman Bros., Chicago, Ill.
Stephens-Adamson Mfg. Co., Aurora, Ill.
The Strong-Scott Mfg. Co., Minneapolis, Minn.
Todd Dry Dock Eng. & Rep. Corp., Brooklyn, N. Y.
Williams Patent Crusher & Pulverizer Co., St. Louis

Correction Note

DURING A press run one of the letters fell out of a formula on page 64 of this issue. As a result some copies of this issue will have an incorrect formula for the flow of gas in pipes. To avoid errors correct your copy to read:

$$Q = C\sqrt{\frac{10D}{L}}$$

DELRAY POWER HOUSE No. 3 of The Detroit Edison Co., a view of which is shown by courtesy of that company on the front cover, is now under construction and will be completed by September, 1929, with full provision for coal handling, preparation and storage. The storage space and preparation house will be located in the foreground of the present construction view, with the inclined belt conveyor entering the top of the boiler house through the opening seen below the base of the nearer stack.

Power Topics Discussed at A.S.M.E. Meeting

INTEREST SHOWN BY MECHANICAL ENGINEERS IN PROBLEMS OF HEAT BALANCE, COAL PULVERIZERS AND PEAK LOADS IN POWER STATIONS

AT THE FORTY-NINTH annual meeting of the American Society of Mechanical Engineers, held in New York City on December 3 to 7, a large variety of topics was discussed, dealing with practically every phase of mechanical engineering but there were not as many papers, bearing directly on power generation, presented as are usually included in these meetings. The interest in power topics, however, did not show any indication of waning, judging from the attendance at power sessions and the discussions that took place.

Business sessions of the Society were presided over by the president, Alex Dow, president of the Detroit Edison Co. and the newly elected officers are: President, Elmer A. Sperry, Sperry Gyroscope Co., Brooklyn, N. Y.; vice-presidents, William Elmer, R. L. Daugherty, and C. E. Gorton; managers, Charles M. Allen, Ely C. Hutchinson, and Robert M. Gates; delegates to the American Engineering Council, Elmer A. Sperry, chairman, E. O. Eastwood, D. E. Foster, W. P. Hunt, O. P. Hood, Charles Penrose, F. A. Scott, Max Tolltz, E. N. Trump and D. R. Yarnall.

One of the most interesting papers presented was that entitled Balancing Heat and Power in Industrial Plants, by R. V. Kleinschmidt of Arthur D. Little, Inc. In this paper, he called attention to the fact that industrial plants use large amounts of heat in such processes as drying and evaporating, water heating, cooking and digesting, and in kilns, furnaces and ovens. Practically all plants in the northern states have substantial space-heating load during six months or more of the year. Moreover, all industrial plants have power and electric lighting loads. In plants like paper mills, textile finishing mills and chemical factories where there is a substatial heating load, the possibilities of generating power as a by-product of the process steam presents an opportunity for possible economy. When all of the power used in the plant is thus generated without rejection of heat in the condenser water, the power and heat loads may be said to be balanced.

In his paper, the author discussed the most important factors that determine or affect this heat power balance. These factors he enumerated as boiler steam pressure and superheat, the pressures and temperatures required by the process, the type and characteristics of power-generating equipment, and the utilization of waste heat.

In attempting to balance the heat and power loads of an industrial plant, the first step, he pointed out, should be a careful survey, involving accurate measurements of the heat and power required by the various processes.

In the discussion which followed the presentation of this paper, R. A. Langworthy stated that he believed there are too many industrial plants having use for process steam that use live steam through reducing valves for this purpose. Manifestly, the lower the pressure on the process, the greater the amount of power which can be taken out of the steam before it is so used. Thorough study of process work is necessary in deciding on the equipment to be used in obtaining a heat balance. Another factor is the coöperation needed between the factory executives and the power engineer. He also called attention to the fact that steam accumulators have been used to advantage in many industrial plants in working out a heat power balance and hoped that industrial plants will some day see the possibility of generating cheap power to feed into the inter-connected power systems now in existence.

Stress was laid by F. M. Gibson on the necessity of a very accurate survey of the industrial plant in order to secure proper balance. Not only the plant as it exists today, but a consideration of the plans for future development must be taken into account. He was of the opinion that the time is approaching when the major considerations will be the balancing of heat and power in a group of plants rather than of the isolated plant.

Another point was brought out by Andrew A. Bato, who stated that in Germany briquet plants use vapor resulting from the drying processes to warm water which is later brought to the boiling point under vacuum and the steam used for driving low-pressure turbines. He also spoke of the value of heat exchangers in steam laundries and cited an instance where exhaust steam at 15 lb. pressure is used in steam mangles.

In the opinion of I. E. Moultrop, there is as much opportunity for improvement in the matter of heat balance, in industrial plants as there was a few years ago in central stations. He also stated his belief that a careful study followed by a moderate expenditure of new capital for rearrangement of the equipment which utilizes heat will quite often, in fact nearly always, pay a handsome dividend on the money and effort expended.

RESEARCH IN HYDRAULIC TURBINE DESIGN

Some Interesting European Hydraulic Turbine Research was the title of a paper presented by Blake R. Van Leer, assistant secretary of the American Engineering Foundation, the purpose of which was to bring to attention certain turbine researches and their results which, although publicly known in Europe, are not generally known to the engineering profession in America.

As is well known to all hydraulic engineers and designers, our turbine theory is very imperfect. Consequently, after the theory has given a lead, the only sure way of ascertaining the truth is by investigation. The whole German turbine design has been based for a long time upon experimental research.

In a paper entitled The Materials-Handling Problem in the Public Utility, John C. Somers, production engineer of New York City, summarized the problem in general terms with specific reference to the central station industry. He stated that the services of this industry necessitated three important physical qualities, namely, capacity, availability and continuity, and in discussing the problem spoke of the engineering organization necessary, the methods of procedure in the selection

of equipment, the function and uses of equipment, conditions of installation, conditions of use, means of operation, and the cost problems involved.

He stated that in general there are certain items which are significant in the solution of the handling problem in the utility. These are: periodic checkup on overall conditions, constant study and observation of trend and development, selection and proper justification of equipment, satisfactory installation of equipment, and standardization of operating conditions. A consideration of these items will be of definite value to the utility engineer in the solution of his problems involving materials-handling.

Comparing Diesel Engine Performance

Otto Nonnenbruch of the De La Vergne Machine Co. read a paper entitled A Simple Method of Comparing Oil Engine Performances, in which analyses were made of a number of reliable tests made on Diesel engines to determine fuel consumption per brake horsepower-hour and per indicated horsepower-hour.

He found that the friction load in all cases is constant over the whole load range and that the fuel consumption per indicated horsepower-hour at low indicated mean effective pressure is practically the same for all types of engines. This and the regularity with which the indicated fuel consumption increases with increasing indicated mean effective pressure, make it possible to derive the indicated fuel consumption and the indicated horsepower of an engine from brake fuel consumption tests without indicator cards. The procedure was illustrated by examples and the general rating of Diesel engines at a standard indicated fuel consumption was suggested.

From these investigations, the author concludes that the fuel consumption in pounds per brake horsepower-hour rests on two factors: the consumption in pounds per indicated horsepower-hour, which expresses the efficiency of combustion; and the friction losses, which may be expressed in mean pressure, and which show mechanical efficiency.

Curves illustrating the paper showed that the indicated consumption at low mean indicated pressure approaches 0.28 lb. for all engines. Also that the commercial full load rating lies at about 0.315 lb. per i.hp-hr. Such rating is evidently good practice, justified by commercial success, and might be suggested as a basis for the rating of engines in general.

In discussing this paper, Edgar J. Kates stated his belief that the method proposed for comparing oil engine performances is ingenuously simple and tells a story to the engineer that is not imparted by the familiar curve of fuel consumption and brake horsepower. This method, he believes, will be an aid to the purchaser and user of oil engines.

Herman Lemp agreed with the author that the friction load is in all cases substantially constant over the whole range, a condition which he had accepted for some time. He has checked the 25 per cent output on one make of engine and found its value to be 0.276 lb. fuel consumption per indicated horsepower-hour, which verifies the author's figure of 0.28.

That commercial pulverizers vary greatly in their performance, was brought out in the paper entitled Coal Pulverizers presented by W. J. A. London, consulting engineer of Walden, New York. It is generally accepted that the power consumption per ton bears a direct relationship to the fineness of the fuel. The power consumption at 60 per cent through 200 mesh varies from 13 kw-hr. per ton to 22 kw-hr. per ton, according to the data given in the paper. Taking the 13 as a basis, it was pointed out that a difference of no less than 70 per cent is shown between one figure and the other.

Looking at the subject from a strictly engineering standpoint, this cannot be said to be a flattering commentary on the state of the art today. There are few examples in engineering practice where we see such a large discrepancy in the performance of commercial machines. It is generally accepted that there are only two actual principles employed today in the different mills on the market, attrition and impact.

From the results of his study, the author came to the conclusion that until we know more about the art of pulverizing coal than we do today, the builders should be honest with the purchaser in any guarantees they make. Engineering judgment prompts us to confine all of our guarantees to the following simple code, which was presented for discussion:

1. Guarantees for power per ton and maintenance to be based on one accepted standard grade of coal.
2. Moisture content under guarantee conditions must not exceed 5 per cent.
3. Fineness guarantees to be based on 99.5 per cent through a standard 40-mesh screen.

C. J. Jefferson stated that he does not think it at all practical to set a definite standard on the degree of fineness required which will cover all boilers. On the one hand, excessive power may be called for in obtaining the specified fineness while on the other hand, failure to call for the required fineness will result in impossible combustion conditions.

Influence of Coal Type on Radiation in Boiler Furnaces was the title of a paper presented by W. J. Wohlenberg and R. L. Anthony, both of Yale University, which included the results of an application of the methods and data, presented in a previous A. S. M. E. paper, to pulverized coal for a number of coals of widely varying composition. After an evaluation of radiation quantities for each of these coals, further investigation was made for the purpose of ascertaining what quantitatively measurable property of coals might be most significant in differentiating one from another during combustion with respect to the quantity of energy which is transferred as heat to the walls of the boiler furnace. It was found, of the properties investigated, that the calorific value serves as the most consistent and useful indicator of the radiation powers of the coal as burned in the pulverized form in boiler furnaces.

Providing for Peak Load in Central Station

Professor A. G. Christie of Johns Hopkins University presented a paper entitled The Peak Load Problems in Steam Power Stations, which dealt with the problems of the annual peak load. The use of the load duration curve for the purpose of studying annual peak loads was analyzed and the conclusions drawn that the plant intended for annual peak load service should be in-

stalled only at the lowest possible first cost, and that economy of heat load equipment can be sacrificed to secure low initial cost.

Various schemes that have been proposed to provide equipment for carrying the annual peak load, were analyzed. The three plans that appear most promising are those involving the use of steam accumulators, of peak load units, and of present plant after new base load equipment has been added.

In order to indicate the possible annual savings through the application of these three methods, the author assumed an electric system with a maximum annual peak load of 200,000 kw., together with certain data from annual load factors of 65, 45 and 25 per cent on this system. With certain assumed plant costs, fuel costs and operating performances, an analysis was made of the annual operating costs of the various methods and the possible annual savings through the use of steam accumulator plants or peak load units were shown in the form of a series of curves.

In the discussion which followed the presentation of this paper, no one present questioned the deductions arrived at by the author, based on the assumptions which he made. Several questioned, however, the possibility of finding a plant which would offer the conditions approximating the assumptions which he made and doubted very much that the conditions of this problem will be encountered in central stations.

I. E. Moultrop, in discussing the paper, wished to call attention to the fact that a base-load station does not exist. That while stations have been built for this service they invariably operate as base-load stations only part of the time. He is of the belief that it is impossible to avoid having obsolete equipment in a power plant, due to the rapid advancements being made every year in the art of power generation.

R. V. Kleinschmidt stated that he believed peak loads on central stations will grow better or worse, depending on whether the central station or the industrial plant engineers are the more wide-awake in relation to the purchase or generation of power.

George Orrok called attention to the fact that many changes have been made in boiler practices which have flattened out the efficiency curve and thus relieved the central station of the necessity for stored steam which existed a few years ago.

Midwest Power Engineering Conference

PLANS ARE practically completed for a four-day conference to be held in the Palmer House, Chicago, Feb. 12 to 15, 1929.

Registration will be opened on the fourth floor, Tuesday morning, the 12th, at 9 a. m., and a luncheon at 12 o'clock will open the meetings, the address being by W. L. Abbott, president of the Conference and chief operating engineer of the Commonwealth-Edison Co.

Papers for the afternoon session, starting at 2 o'clock, will deal with Sub-Structure Problems. Design and Construction of the Stream Flow Plant at Louisville, Ky., will be discussed by H. G. Roby of the Byllesby Engineering and Management Corp'n. Power Plant Sub-Structure Problems will be treated by J. C. Sanderson of Sargent & Lundy. Sub-Structures for Steam Power Stations in Various Localities will be described by P. E. Stevens of the Byllesby Engineering & Management Corp'n.

For Wednesday, three sessions and a banquet are scheduled: A morning session at 10 o'clock on Metallurgical and Chemical Problems of the Power Plant; a luncheon meeting at noon under the auspices of the American Institute of Electrical Engineers; an afternoon session at 2 o'clock on Electrical Engineering Problems; a banquet at 7 o'clock followed by dancing in the grand ball room. Papers for the morning will be Metallurgy of Power Equipment Material, by A. E. White of the University of Michigan; Researches in Corrosion, by K. H. Logan of the U. S. Bureau of Standards; Power in Chemical Industries, by Dr. C. M. A. Stine of the DuPont Co.

For the afternoon, papers will be, Synchronous Supervisory System and Telemetering, by C. E. Stewart of General Electric Co.; Sight Seeing Among the Atoms and Molecules, by Professor G. L. Clark of the University of Illinois.

Thursday's sessions will be at 10 a. m. on Problems in Heating, Ventilation and Refrigeration; a luncheon meeting arranged by the Western Society of Engineers at noon; an afternoon meeting at 2 o'clock on Power Plant Operation.

Morning papers will be, Refrigeration and Ventilation Principles in Everyday Use by S. C. Bloom, consulting engineer; Refrigeration in Preservation of Foods by A. J. Authenrieth of the Middle West Utilities Co.; Research Applied to Heating and Ventilation by Samuel R. Lewis, consulting engineer.

Afternoon papers will be, Centrifugal Pump Economics by Professor A. F. Scherzer of the University of Michigan; Coördination of Industrial Plant and Central Station Power by P. J. Gaudy of Sessions Engineering Co.; Welding in Power Plant Construction and Maintenance by H. H. Moss of Linde Air Products Co.

On Friday a morning session at 10 o'clock will be devoted to Power Plant Economics with papers on 1200 Pounds as a Dollar Saver by Edwin Jowett of the Kansas City Electric Co.; on Plant Practice and Engineering Insurance by J. P. Morrison of Hartford Steam Boiler Inspection & Insurance Co.; on Modern Stoker Equipment by Dr. C. F. Hirshfeld of the Detroit Edison Co.

Topics have been chosen to cover a wide range of interest and subjects of vital importance and, as the above program shows, speakers of the highest authority and reputation have been secured.

TWO ANCIENT walking-beam steam engines, both of which saw many years of useful service in the old 6th St. gas works of the Public Service Electric and Gas Company of Jersey City, will be indefinitely retired on a pension and will spend the remainder of their days in museums. One of them will go to the Franklin Institute in Philadelphia while the other will find a home at the Stevens Institute of Technology in Hoboken. At the time of its original construction in 1850, this plant was one of the largest and most efficient in the entire country, having a capacity of some 2,000,000 cu. ft. of gas a day. In its hey-day, this old plant served as a school of instruction for many engineers now prominent in the gas industry.

Seventh National Exhibition of Power and Mechanical Equipment Is Held in New York

WITH THOUSANDS of engineers in attendance from all parts of the country, the Seventh National Exhibition of Power and Mechanical Engineering was held at the Grand Central Palace, New York City, from Dec. 3 to 8. Estimated total attendance for the week, as given by the management of the exposition, was approximately 118,000, while the total registration, based on that of the first four days, was estimated at about 28,000.

In the exhibits, 214 manufacturers showed power plant equipment, 159 heating and ventilating equipment, 62 refrigeration equipment, 80 electrical equipment, 48 material-handling devices, 64 power transmission apparatus, 126 machine shop tools and woodworking machinery and 40 safety equipment.

Visitors to the exposition, many of whom came from foreign countries for the occasion and also to attend the annual meeting of the American Society of Mechanical Engineers saw a most varied display of all types of engineering equipment. Four lower floors of the Grand Central Palace were occupied by the exhibits.

New stokers, both for power boilers and of the smaller types for heating boilers aroused interest, as well as several displays of oil burners for power and heating service. New types of furnace refractories, especially designed for use with water-cooled furnace walls, were

INSTRUMENTS AND VARIOUS TYPES OF CONTROL EQUIPMENT ON DISPLAY SHOWED PROGRESS MADE DURING YEAR

shown by actual sections. Insulating material for furnaces was shown in profusion, in both blocks, and plastic types, as well as specimens of underground pipe construction and typical displays of valves and fittings among which new types of motor operators for valves were included.

Regulators for furnace draft and other purposes pump governors, a new desuperheater governor, new equipment for automatic and pressure lubrication of equipment were featured. There were several new designs of steam traps and air eliminators for heating systems.

Of principal interest to the heating and ventilating engineers were various new systems for controlling heat in various sections of heating systems, new thermostatic control devices and several types of unit heaters, including one designed also to use refrigerant in the heating element. Various fans for ventilating service were shown.

Interest of power plant engineers in elimination of fly ash and cinders from flue gas was reflected in the displays of two manufacturers of devices for this service.

Measuring instruments for flow, pressure, temperature, and other factors were exhibited in new designs, as well as several new electrical meters and a new diaphragm type of flow meter. Many new designs of flush type instruments for panel mounting were seen.

Motor controllers and new motor designs attracted attention. Several companies showed new circuit breakers of both air-break and oil types. A working model of an automatic supervisory control system was of interest.

Bearings, reduction gears, belting, gearing and power transmission apparatus in general received much attention and many manufacturers showed new designs of material-handling equipment, such as screens, hoists, conveyors and the like.

For the industrial engineer, there was a profusion of machine tools and woodworking tools designed to speed up production, perform unusual operations and promote safety practices. It is interesting to note the number of exhibitors that emphasized the safety aspect either in design of equipment or in methods, or both.

Considerable attention was attracted to a display of various mechanical control devices for machinery based on the principle of the torque amplifier shown for the first time last year.

Spectacular demonstrations of high frequency apparatus by the General Electric Co. attracted the attention of almost every visitor on account of the almost incredible actions of the demonstrators in lighting gas tubes, heating metal and performing other operations with "only a little coil of wire" as one man described it.

Detroit Edison Co., in an extremely instructive display, showed how models are used in its design of power plants or other projects, especially for piping design, the pipe models being made of wax sticks by a special process. Consolidated Gas and Electric Co., in an impressive exhibit, showed many of the uses of gas in industrial processes.

Stopping before the booth of The Foundation Co., the observer seemed to be looking out over a great power plant in process of construction. In the foreground was an actual caisson with pumps and other actual equipment while at the rear of the booth was a painting depicting an actual scene during construction work on the foundations at the West End Station in Cincinnati, built several years ago. Here five different methods of foundation construction were used.

Port of New York Authority showed a display of models used in design of its projects, such as the Kill Van Kull bridge, drawings and models of the new Hudson River bridge and sections of cable.

On Monday evening at 9:30, the visitors at the Exhibition were addressed by Senator Henry F. Ashurst of Arizona. Senator Ashurst called especial attention to the rapidity with which the modern marvels of the power plant and of science and engineering, which we often take for granted, were developed. He reminded his hearers that almost all of them could actually remember the time when there was no such thing as radio, the aeroplane, the motion picture, the 165,000-kw. turbine generator. He predicted even greater strides in the future, and said that in view of the past developments no man should ever ridicule a new scientific notion.

A message of congratulation to the Exhibition was also received from Charles M. Schwab.

During the course of the exhibition, a varied program of motion pictures showing industrial methods and devices, was presented in a conference room on the fourth floor of the exhibition.

Instruments and Meters

Ellison Draft Gage Co. had on display several models of its new mercury element pointer draft gage. This is designed to meet the demand for draft gages reading from 10 in. to 50 in. of draft or from 1 to 2 lb. pressure, as total draft in many large boiler houses is often as much as 20 in. To do this without making the gage too cumbersome and complicated, use has been made of a mercury element, consisting of a well 1¾ in. in diameter containing mercury with oil on top, and a bell 1 in. in outside diameter in the well. The motion of this bell, produced by variations in draft, is transferred by the usual Ellison straight line motion to the pointer moving over a vertical scale.

C. J. Tagliabue Mfg. Co. called attention to its new line of round case, flush type panel board recording instruments. Except for the change in case, the operating principles and construction of these recorders remain the same.

Brown Instrument Co. called attention to its new line of flush type circular and rectangular cases for recording instruments. The circular recorders are made with a flange to be bolted through the panel so that the instrument can be locked when shipped, to keep out dirt. On the flush type continuous recorder, with rectangular case, an unusual feature is the mounting of the entire recording instrument on a frame supported by rollers running on rails, so that the entire unit can be pulled out on the rails through the front for inspection or replacement of any of the parts.

Another new Brown instrument was a combined pressure gage and inductance bridge unit for transmitting and recording pressure at distances up to 5 mi. if necessary. In this gage, a spiral pressure element

is actuated directly by the pressure to move a lever connected to the armature of the divided inductance coil.

Exhibition of the new gage cock with safety stop was made by Ernst & Co. On this cock, a quarter turn blows the valve but the ball does not seat. The lever is held from more than a quarter turn by a stop which, when pushed back, allows the lever to turn further and permits inside steam pressure to force the ball to its seat so that the valve disc can be taken out. A new water gage with split gland packing nuts and hand wheels for tightening them was also shown.

Handy Bristol's Recorder, a 6-in. circular chart instrument, was shown by The Bristol Co. This is a portable recording thermometer designed especially for use in cold storage rooms, apartment houses, schools and so on, as recently described in these columns. There was also a new three chart recorder.

EXHIBITS FEATURING REFRACTORIES, INSULATING MATERIALS, DUCT DESIGN, GASOLINE ENGINES

Diaphragm meters, type GK, a new type, were on display by Builders Iron Foundry. These are designed for registering, indicating and recording flow of fluids. The meter operates by direct mechanical connection to a diaphragm, which is moved by direct fluid pressure transmitted from an orifice in the pipe line. Electric transmission is not employed. The orifice creates a

pressure differential as the fluid passes through it. The diaphragm, restrained by two phosphor bronze springs and partly supported by a conical shield, is displaced by the pressure difference. This displacement is transmitted through a crank and shaft to an indicator hand.

Leeds & Northrup Co. exhibited a new frequency controller using the same element as that of the recorder; this device is to control frequency of a generator driven by a steam or water turbine by direct connection of the controller to the governor regulating motor on the turbine. A new generator field (rotor) temperature recorder was also shown. This device measures the field resistance with a Kelvin bridge and records it directly in temperature. A portable frequency indicator, using the same impedance bridge principle as the frequency recorder, was shown. This is stated to have an accuracy of 0.1 cycle.

Refractories and Insulating Materials

The new Moler insulating brick, made by Skarrehage Moler Works, Inc., was shown at the booth of F. L. Smidth & Co. This brick is made of a material known in Danish as Moler and has been used in insulating cement kilns and many other types of industrial furnaces. The bricks are made in various weights, with melting point of 2430 deg. F. It is applied in solid slabs in various sizes up to 24 by 12 by 3 in. for insulating boilers.

Kingdo refractory patch and Kingbond were two new products shown by King Refractories Co., Inc. Kingdo is a furnace lining material designed for repair work on furnace walls. It is applied in plastic form and is intended to be forced into any crack or crevice or as a patch when any part of the furnace wall starts to deteriorate. Kingbond was stated to be a dense, plastic refractory material designed for bonding firebrick, also as a refractory lining.

New insulating brick were displayed by Armstrong Cork and Insulation Co., designed for insulating boiler settings, furnaces, and other high temperature equipment. The brick are designed to withstand 2500 deg. F. without spalling. They are to be laid and bonded to the refractory when the setting is built, being laid with thin joints, using a batter of Armstrong's insulating cement. For most purposes, a 4½-in. thickness of the brick is sufficient. They are designed for a compression strength of over 200 lb. per sq. in. and each brick weighs about 2 lb. They can be furnished in all shapes and sizes.

Rineheit high-temperature insulating refractories, weighing 3½ lb. per 100 cu. in. and possessing high fusion point, were shown in many shapes and sizes by The Mutton Hollow Fire Brick Co.

General Refractories Co. showed its new Standard silica bonding cement for bonding fire clay and silica brick, patching and general repair work. This is an air-set cement.

Full-sized sections of the Seymour-Carbofrax boiler furnace were displayed by both the Carborundum Co. and Erie City Iron Works. In this furnace, the walls are cooled by water tubes on which a specially-designed Carbofrax block is placed. These are shaped so that they fit closely between and over the tubes, to present a flat surface on the inside of the furnace. With boiler furnaces of this type, it is stated that heat release of 50,000 B.t.u. per cu. ft. per hr. have been obtained in regular operation.

At this booth, and also at the booth of Bernitz Furnace Appliance Co. was shown the Nygaard water wall, made by the latter company. In this wall also, the water cooling tubes are covered with Carbofrax blocks designed to give perfect contact, to be removed and replaced from the fire side, to be interlocking without clamping devices, to allow for expansion and to permit combustion right up to the face of the wall.

Cork Foundation Co. had on display specimens of its new sound-deadening materials: Absorbit for walls and Absorbo-phone for floors. Absorbit consists of three layers of fibrous material impregnated with asphaltum and laminated. It comes in standard size, 48 by 48 by ¾ in. and is intended for making soundproof walls. Absorbo-phone consists of strips of natural cork dipped in asphaltum and placed criss-cross on the floor slab, with finely ground cork packed between the strips and a layer of asphalt felt over all.

At the booth of Insulating Products Corp. a section of an insulated fin tube water cooled furnace wall was shown. This was first given a coating, with a trowel, of about ½ in. of a mixture of Webers 48 and a new semi-refractory, known as No. 1800, made by Refractory & Engineering Corp. Over that coating was placed 3 or 4 in. of Webers 48. In this form of wall covering, clips are welded to the outside of the fin tubes, with cable stretched between the clips to form support and reinforcement for the insulating material. This permits small sections of the insulation to be removed, when necessary, without disturbing the remainder. It was stated that the use of the No. 1800 did not require the use of forms in installing it.

New Stoker Is Displayed

Neemes automatic stoker, a new product of Neemes Foundry, Inc., was displayed by a full-sized working model. The stoker front with hopper replaces the lower half of the boiler front and the stoker consists of two sections of bars extending across the furnace, actuated by levers from below, with provision for timing the sections to suit conditions or fuel. Upper and lower sections may be operated independently of each other to bring the lower section into use more than once to clear away ash. Individual sections may be operated at intervals of from three to 30 min. and, by engaging a pawl by hand, any section can be operated at any time. Drive is by a ½-hp. or 1-hp. motor through a reduction gear but the stoker may be hand operated in emergencies. Coal feeding mechanism consists of a series of feeders extending over the entire width of the furnace to give uniform distribution of fuel, which is fed across the furnace in comparatively small amounts at a time. Dump plate is shaped so that fuel will completely cover it again after dumping and is operated independently of stoker bars. All air admitted over the fire is preheated and there are three separate means of admitting it over the fire, to give turbulence of furnace gases. Automatic control apparatus starts and stops the coal feed with slight variation in steam pressure and adjusts the boiler damper to suit the rate of combustion.

Electrical Equipment

Exhibition of high frequency apparatus attracted much attention at the booth of General Electric Company because of its spectacular nature. Frequencies of 3,000,000 cycles or more were used. One display showed how vacuum tube elements could be heated during construction by merely holding them inside a high frequency coil, with no outside electrical connections to the tube. Glow tubes were lighted merely by being placed close to the high frequency apparatus. Photo-electric cells were demonstrated, controlling apparatus by placing the hand between the light and the cell. By polarized light, methods were shown by which strains in celluloid shapes subjected to stress could be actually seen by the changing of colors, a process used in analyzing internal strains in metal.

Automatic supervisory control equipment of new design was shown in operation. This is designed to control as many as 90 circuit breakers over 4 wires. The despatcher can select the breaker he wants, get a light signal showing its condition, operate the breaker by a key and receive an audible and visible signal when the unit has operated. He can also read alternating current and voltage at any point over the same wires. If anything is short circuited, the signal system indicates it and operations cannot be started.

New G-E constant-speed, single-phase motors, Type S C R were also shown. These are from ½ to 10 hp., 60 cycles, from 110 to 440 v. Type FK-33 oil circuit breakers of single and double throw types for manual or electric operation were demonstrated. These are designed for small and isolated installations for 4500 v., 200 and 400 amp. Another oil breaker, Type FKR-55, was shown, of the triple-pole, single-throw type, for 7500 and 15,000 v., 400 to 3000 amp. Type CP-8 air circuit breakers for moderate duty service were in operation. These have the trip free from the handle and are automatic, either instantaneous or time. They are of the triple contact construction for 650 v. a.c. or d.c., 1200 amp. and below, and of single, double or triple pole types.

Cutler-Hammer Mfg. Co. showed a new combination slip-ring motor controller, including a magnetic primary switch for motors up to 15 hp., 550 v. This is manually operated with interlocks on the primary and thermal overload protection. Here also was shown a new water level alarm system to give automatic indication of water level in a fire protection system, water supply system or similar application. This operates from a float switch and gives visible and audible signals. The new size A0 valve control unit for valves 1½ to 3 in. in size was displayed. The non-fragile grid resistor, designed originally for steel mill duty, was displayed. This is of continuous strip with steel supporting frame and adjustable connectors, mica insulation being used throughout. It is designed to give free ventilation and has a large surface for the low resistance taps.

Special attention was called by I-T-E Circuit Breaker Co. to its new full-automatic, double-throw transfer switch for hospitals and theatres, of which a 1000-amp. unit was displayed. This switch is designed so that in case of failure of main current supply it will automatically switch the circuits over to the auxiliary supply and when the voltage comes on the main line again, will automatically switch them back. Another interesting new product was the all-steel U-Re-Lite panel with either alternating or direct current remote controls. These panels are assembled at the factory and carry U-Re-Lites for across-the-line starting, in sizes to fit the conditions. They have single-phase protection and are non-closable against a short on the line. They can also be operated manually if necessary. The display panels carried the Type W units made for from 5 to 400 amp. with rupturing capacity of 30,000 amp. at 480 v., 3 phase, 60 cycles. Attention was also called to the Type L X circuit breaker made in capacities up to 1250 amp. at 550 v., with a rupturing capacity of 40,000 amp.

For clarifying transformer and regulator oils, the new portable combination centrifugal purifier and filter was shown by The Sharples Specialty Co. It consists of a Sharples centrifuge with its driving motor pump and accessories and two 7 by 7-in., 10-g.p.m. each filter presses mounted on a frame on wheels. For transformer oils the filter presses are not used, but with regulator oils, either press or both can be used. The model shown had a capacity of 900 gal. an hr.

Ash and Dust Gates

Improvements in draining of its ash gate were shown by the R. H. Beaumont Co. by a full size gate in operation. The drain is now swung on a hinge so that by a slight movement of the operating lever it can be swung entirely clear of the path of discharging ash. Then the ash gate is opened, ash discharges, a pull on the lever closes it and after it is closed the final motion of the lever returns the drain to its normal position. The object of the arrangement, of course, is to prevent ash from clogging the drain.

For use on bottoms of large dust tanks, Allen Air Appliance Co. called attention to a new gate construction for the tank bottoms. This gate is swung on an arm, with the suspension point offset so that it swings away from the discharging dust. When closed a swivel and ratchet mechanism centers it and closes it tightly.

Heating Systems and Controls

Remote control valves for zone control of heating systems were shown by Illinois Engineering Co. These valves serve to vary the steam supply to a zoned system, under control of a thermostat in each zone. They are motor-operated, with an arrangement of gears and spring lever connection to valve stem to prevent stalling. They are also designed to act as pressure reducing valves in addition to their zone control action, to keep a constant pressure on each zone depending on the conditions. They can be operated by push-button from a central control point.

At the booth of C. A. Dunham Co., a newly-developed sub-atmospheric pressure and temperature control valve was shown, as used with the company's differential vacuum heating system. This system is arranged to provide for control of amount of steam sent to various parts of the heating system in response to variations in the room temperatures. Thermostats in various parts of the building actuate the control valves, which are designed to provide a sub-atmospheric pressure in the system until the required vacuum is reached whereupon the valve admits steam to the system.

At the booth of Grinnell Co. was displayed the duotherm control, developed for regulating room temperature with unit heaters. This is designed to give remote control; several of the units can be actuated by a high-low remote control master push button station. Dual thermostats controlling high and low temperature are located at proper points in the rooms to be heated and these control the operation of the fans in the unit of air at 1000 ft. per min. was in use with steam to heat air and another of similar capacity was used with a refrigerant to cool the air. Attention was called to the one-piece integrally-cast aluminum heating section with stream-line core and absence of joints. Standard units are 3, 5 or 7 sections wide; the fan, driven by a standard motor, is of four-blade aluminum construction. Sizes range from 1000 to 6500 c.f.m. of air.

NEW TRAPS, AIR ELIMINATORS, CONTROL VALVES AND PUMPS FOR HEATING SYSTEMS WERE EXHIBITED

heaters. There was also shown the new I-beam clamp for supporting pipe up to 24 in. in size on I-beams. Three sizes are made to care for all pipe sizes. The clamp, of wrought iron, is adjustable and consists of two hooks fitting over the lower flange of the I-beam, their opening being adjusted by a rod with units at the end and a rod hanging down to support a pipe hanger.

The Thermolier shown here is a unit heater for industrial use. It has a heating element of copper tubing on which fins with tight fitting collars are pressed, the collars being used to give strength and good heat transfer. A motor-driven, 4-blade fan with cast bronze hub and aluminum blades forces air through the heater.

Thermal units designed for either heating or cooling were shown in operation by The Thermal Units Co. One of these units, with a capacity of about 3000 c.f.m.

The Webster Moderator System of steam heating was announced for the first time at this exhibition. Data were issued in response to many requests but Warren Webster & Co., its manufacturer, states that owing to certain characteristics of the system it is not prepared to accept orders on a production scale. Briefly, the system is designed to provide for fully automatic variation of steam, to provide for changes in demand resulting from variation of outdoor temperature, turning on or off of radiation, variation of steam pressure or vacuum. This is supplemented by manual variation of steam supply to compensate for changes in steam demand caused by conditions other than temperature variation, for night loads or heating up. To secure these results, the moderator system employs a main steam control valve and a number of orifices in the steam mains, the amount of steam passing to the

system being varied by the operation of the valve under the control of a roof thermostat actuated by outside temperature variations.

Steam Traps and Air Eliminators

Low pressure return trap and air eliminator for vapor heating systems was the principal new product displayed by Kieley & Mueller, Inc. This consists of a seamless copper float on a lever which operates a double-ported valve when condensate collects in the trap. As the air has been forced out of the system into the trap ahead of the condensate, it passes out the vent valve but as the float rises on the condensate, it closes the vent, opens the steam valve and discharges the condensate to the boiler by gravity.

Two new steam traps were displayed by Strong, Carlisle & Hammond Co. In one of these, the Anum-metl trap, 40 series, the design of the body is cylindrical and the bucket hinge rod, valve hinge rod, valve rod and lever, as well as valve and seat, are now of Anum-metl. This is a bucket trap, in which filling of the bucket opens the valve and permits discharge. The second new trap, the 20 series, is an inverted bucket type of trap, in which raising of the bucket by rising condensate operates the valve, which with its various connecting rods is of Anum-metl. The Strong Evrtyte valve was shown in a new design; in sizes up to and including 1 in., the body of the valve is now made from bar stock.

New air eliminator for steam heating systems was shown by Sarco Co., Inc. This is installed so that when steam is admitted to a heating system, the air from piping and radiators is forced through the return line to the air eliminator where it is freely vented. It consists of a cast-iron body, a copper float and a brass valve mechanism for venting air. If water should accumulate in the return, the float rises against the lower check valve to prevent escape of water. When steam is condensing in the system, the upper check valve prevents air from being drawn into the system.

The new Curtis Type T return trap, at the booth of Julian d'Este Co., attracted attention. In this trap all operating parts except the float are outside. The float actuates a pilot valve which admits steam or water pressure to the diaphragm of an equalizing valve. At the same time, the vent valve closes, its operation being synchronized with that of the other valves. The opening of the equalizing valve causes steam to equalize the pressure and the condensate discharges from the trap.

Bearings and Power Transmission Equipment

New Dodge-Timken Type C bearings were a feature of the exhibit of Dodge Mfg. Co. These bearings, as special feature, have abrasive dust closures. It was stated such bearings were mounted on a shaft enclosed in a box with cement and operated for 150,000,000 revolutions (equivalent to 16 mo. service at 600 r.p.m.) the atmosphere in the box being kept agitated by a fan. At the end of this test, it was stated that no dust had entered the bearings.

Several interesting control devices, developed on the principle of the Bethlehem torque amplifier, described in last year's report, were displayed by Bethlehem Steel Co. One of these, the snub-starter, is designed for use with constant speed electric motors driving machinery which has such great inertia as to cause heavy starting torque; its object is to impart to the driven machine a slow start with uniform acceleration.

Another device developed from the torque amplifier was the S-I-S drive for starting, inching and stopping machinery.

A third development of the same principle was the Bethlehem reel drive and tension control, designed for use on reels, winders and spoolers to maintain a uniform tension on material being wound or unwound in spite of the changing diameter of the roll.

New speed reducers of the herringbone gear type were shown by W. A. Jones Foundry & Machine Co. These have herringbone continuous tooth gears, Timken roller bearings and unusually heavy housings, well-ribbed, with heavy feet and foundation belts. A large oil reservoir is provided for the oil bath in which the gears run.

Reeves Pulley Co. displayed the new Reeves variable speed transmission with double block belt, compact design of frame, anti-friction bearings and lubricating devices, as recently described in detail in these columns.

Pumps and Compressors

Pennsylvania Pump & Compressor Co. showed its improved air-cushioned valve with four parts: seat, guard, disc and springs. An air cushion pocket in the guard is to prevent the valves from striking the metal of the guard as they open. This valve has been illustrated and described in detail in these columns.

Considerable interest was aroused by a new type of multistage centrifugal compressor displayed by B. F. Sturtevant Co. and designed for handling air or gas at high pressures. The unit, which can be driven either by steam turbine or electric motor, consists of a number of impellers on a common shaft, housed in stationary casings; one stage consists of an impeller and its casing. As air passes from stage to stage, each stage adds an increment of pressure. Volume requirements determine the proportions of the individual stages while pressure depends on speed and design of passages. The units are designed to maintain practically constant pressure over a wide range in volume and to be self-governing.

Nash Engineering Co. displayed a new 30-gal. sewage ejector of the same design and using the same principles of operation as the larger units. Of special interest was the suction sump pump, an open impeller centrifugal for sump service. In this pump an open impeller is combined with a vacuum priming pump in the same casing, so that the pump and its driving motor are of the horizontal type and are mounted above the sump, only the suction pipe being submerged. The priming pump exhausts the air from the casing and when the liquid reaches the impeller the unit operates as a simple centrifugal pump. It is supplied in capacities from 30 to 250 g.p.m.

New series of vacuum heating pumps in small sizes, for 2500 and 5000 sq. ft. of heating surface, were also shown.

O. E. Frank Heater & Engineering Co. had on exhibit several full-sized models of its new oil cooler, drawings of which were shown last year. In this apparatus, shell and liquid channel box are so made that tube bundles are removed without breaking any pipe con-

nections, or a tube can be removed or the unit cleaned without removing the tube bundle.

Manistee Iron Works featured in its display a new 4-stage pump made with volute casing and without diffusion vanes. The hydraulic balance principle is used in the design of the impeller. A unit of this type was shown rated at 900 g.p.m., 560 ft. head, 1750 r.p.m., 74 per cent efficiency and using 84 lb. hp.

Quigley Furnace Specialties Co. called attention to the new Quigley emulsified asphalt gun, an adaptation of the Quigley refractory gun. The asphalt gun is piston-actuated, material being extruded from the cylinder by air pressure admitted under the piston to insure constant and steady delivery to the nozzle. The gun is designed for applying asphalt coating to metal, concrete, brick, cork and other surfaces.

Bakelite-treated metallic condenser rings made by a new process were displayed by Crane Packing Co. In these rings each layer of the material has a surface of special bakelite material. They are designed to resist all chemical action such as might be encountered in marine condensers, and evaporators, heaters and condensers in process work.

The Dampney Co. of America exhibited its new Style D power coater for applying Apexior to bent tubes of boilers. Brushes are on swivels to give straight brush action on the curves and a rubber sound deadener is provided.

Keystone Lubricating Co. displayed its new type C grease cup to supply storage of grease over bearings under pressure. This is a form of the standard cup, arranged so that grease can be fed to it under pressure from the company's pneumatic lubricator, a special adjustable check valve being provided to equalize the pressure on all cups when they are connected to a common supply, preventing back pressure and allowing all cups to receive the same amount of grease.

Pipe-savers, which are liners to be driven into threaded ends of pipes to reinforce the thread and prevent wear, were shown by Pipe-Saver Corp. of America. They have a flange on the outer end and are driven with a hammer and a block of wood into the threaded end up to the flange, which then threads into the coupling with the pipe thread.

Durametallic Corp. showed new packing with elastic cores; an elastic middle section with outer plies metallic. Duraplastic packing, composed of small metallic particles mixed with long asbestos fibers, was also shown.

Valves and Regulators

New seat construction of Everlasting's companion angle valve was featured by Everlasting Valve Co. This is designed so that as the valve closes, the constrictor face retards the flow just before the valve seats, the flow of solids is cut off just as the guide enters the cylindrical wall of the seat but a flow of water continues washing off the sealing face, the sealing ring is lifted out of the path of erosive solids when the valve is fully opened and when closed makes line contact with the seat, being fully protected against erosive action at all times.

On its standard controller, Powers Regulator Co. called attention to the new packless feature. The shaft is now made to fit the hole in the gland follower so closely that no packing is needed.

Klingerit, Inc., called attention to the new one-piece gland on its screwed valve, in place of the former lock nut arrangement. Klinger's packing is now supplied in rings as well as in spiral form. A reflex type water column with flat gage glass for 1800 lb. was also displayed.

Attention was called at the booth of Charles Engelhard, Inc., to a new solenoid-operated, packless type valve for oil, gas, water, air and the like. In this valve, the solenoid plunger slides in a tight housing, sealed by a steel cap forced down on it by a tension spring. This is to prevent leakage due to expansion of the housing. Fluid to be controlled is allowed to flow into the plunger chamber, when the valve is closed, but as this is tight, it cannot reach the coils or do any injury. There is no packing on the shaft between valve and solenoid plunger. The valve is made in sizes from ¼ to 3 in. for 250 v. d.c., or 440 v. a.c.

The Limitorque machine for operating valves was shown in operation on a 24-in. Crane gate valve by Payne Dean at the booth of M. W. Kellogg Co. This is a reversible, motor-driven, reduction gear controller with a mechanical power switch mechanism to limit the torque and travel of a slow speed shaft in both directions. Power may be from an electric or a compressed air motor and may be remotely controlled. The device is designed for application to valves, sluice gates, doors and other equipment. A motor through a chain drive operates a slidable worm shaft, working through the worm that drives the worm wheel on the valve spindle. Movement of the worm shaft by a predetermined amount operates the electrical limiting devices to stop and start the motor at the correct moment. The Limitorque is designed to stop the valve gate only when it is properly seated, regardless of travel or to stop it in case of undue overload during travel.

At the same booth, M. W. Kellogg Co. showed examples of the new Kell-Raph plated steel gasket for pipe lines. This is a seamless steel ring, plated with copper, silver, gold or other soft metal to resist action of the fluid to be handled.

Richardson Scale Co. presented data on a new type of weighing machine, the Convey-a-Weigh. This device employs the apron feeder of its present machine in such a way that amount of material passing on a conveyor can be weighed quickly and accurately during its travel.

A. M. Byers Co. showed a 2290-lb. puddle ball made by its new process of making wrought iron, on which data were presented. This process is designed to secure separate and close control of metal and slag quality and to secure uniformity of the disintegration process and of the reactions essential to producing high quality wrought iron.

Tri-Lok Co. showed its new T-bar armoring, produced by locking the stem of standard rolled T sections with the Tri-Lok joint.

Floorgard, a new armoring for concrete floors, was shown by Blaw-Knox Co. This is a crimped steel, supplied in stock lengths with a special tool for cutting to fit around pipes or other obstructions.

Lubricants and Lubricating Devices

To demonstrate the characteristics of its lubricating oils, such as body and viscosity, the Texas Co. had an

arrangement of rocking tubes filled with oil, each containing a steel ball that pushed its way by its own weight through the oil when the tubes were rocked from one position to another.

Turex, a new type of lubricating oil for steam turbines and Diesel engines, was displayed by Standard Oil Co. of New York.

New filter for oil in pressure lubricating systems was shown by Wm. W. Nugent & Co., Inc. In this device, if the filter becomes clogged, the oil accumulates in the case; as the oil level rises, it raises a float which sounds a bell alarm and lights a signal light. The operator then bypasses the filter, cleans the filter bag and restores the unit to service. This filter is installed between the oil circulating pump and the lubricated machine. Another type of selfcontained filter was shown —not a pressure filter—having 3 bags and a gear pump mounted on the filter for circulating the oil.

The Dot Electric Lubricator was a new product shown by Dot Lubricating Equipment Co. This consists of a motor-driven grease pump mounted on a truck with the grease tank, grease being delivered by a hose connection. Its use is to deliver grease to pressure grease cups. An air pump creates 65—80 lb. pressure on the grease going to the grease pump which develops 220—3000 lb. pressure and is designed to deliver grease to the fittings at 11 oz. per min.

Force feed lubricators of new design were displayed by American Oil Pump & Tank Co. Model N, for machine tools and various types of industrial machinery consists of a single pumping unit discharging oil in sequence to 8 feed lines, each of which is individually adjustable. It starts and stops with the machine and amount of oil discharged into each line is visible. Model P unit operating on the same principle is for greases and heavy oils.

Data were presented about the new Swartwout desuperheater governor by The Swartwout Co. In this governor, a generator in the steam line leaving the desuperheater actuates a diaphragm valve to control the amount of water admitted to the desuperheater, so that all superheat can be removed or some left in the steam, as desired. A reducing valve is provided ahead of the desuperheater, which is usually equipped in addition with a separator and a drainage control system.

Northern Equipment Co. had on exhibit the new Copes Type DS pump governor. This has an actuating element consisting of sylphon bellows, the inside of which is subjected to the pressure of the main steam heater, while the outside of the bellows is subjected to the water pressure on the discharge line of the pump. Changes in pressure influence the sylphon bellows which actuates a weighted lever, the motion of which controls the opening of the valve admitting steam to the turbine or other equipment driving the pump.

New electrically propelled trolley with hoist for transporting loads, to replace the hand trolley for long hauls, was exhibited by Yale & Towne Mfg. Co. This is made in ½ to 2-t. sizes for alternating or direct current and has 8 roller bearings. New ball-bearing chain blocks, in ¼-t. to 20-t. sizes were also featured.

An automatic, motor-operated platform scale with a capacity of 200 lb. was shown by Merrick Scale Mfg. Co., delivering the weight stamped on a ticket.

Dixon's graphite seal, a new product for sealing gasoline and oil lines was featured by Joseph Dixon Crucible Co. This material is designed to resist high heat, to set readily, yet permit the joint to be easily broken, to permit the joint to be pulled up tightly as it expands on heating and to avoid discoloring or contaminating the material in the line.

Morse Chain Co. featured its new flexible coupling, consisting of a chain wrapping two sprockets, one of which has a guide groove to hold the chain in place. The other sprocket has no guide groove and the chain is free to move back and forth on its surface to allow for end play, general misalignment and angular variations.

New Clipper belt cutter for cutting belt from the roll and squaring ends was shown by Clipper Belt Lacer Co. This consists of a knife operated by a hand lever

ONE OF THE EXHIBITS OF AUTOMATIC WEIGHING MACHINES

and is made in 6 in. and 10 in. sizes. A new speed lacer, No. 6, was also shown; in this device, a three-quarter turn of the crank forces the lacing hook into the belt. This model is for 6 in. belt.

Robins Conveying Belt Co. displayed its new Gyrex Screen for material that can be screened. It consists of a rectangular screen frame gyrated, not rotated by a single counter-balanced drive unit. The screen frame is pivoted so that the proper screen angle can be obtained. Drive shaft and counterbalanced flywheels use roller bearings and the design enables the bearings to be placed outside the screen frame, free from dirt or water.

Vertical sinuous air filter of a new design was shown by Midwest Air Filters, Inc. This consists of a row of vertical sinuous filter cells, which bend and accelerate air flow, so that centrifugal force caused by this change in direction and acceleration will cause the dust particles to impinge on the cell walls, the heavier particles on first entering the bend and the other on leaving it. Entering and leaving passages are straight to eliminate eddies on entering and to regain the kinetic energy as pressure, use being made of the venturi principle. The elements are cleaned by flushing them from the top by gravity with Viscosine, which is cleaned at the bottom of the filter and returned for use again by a pump.

Dust Eliminators for Flue Gas

Thermix stack, Type 4, for production of mechanical draft and removal of dust and fly ash from flue gas of stoker and pulverized flue furnaces, was exhibited for the first time by Prat-Daniel Corp. In this unit the Thermix stack is combined with the Type 4 fan, the scroll of which is about twice the normal length. This design is intended to concentrate the dust near the outside periphery of the scroll. By means of an opening along this outside periphery, a portion of the gas—5 to 15 per cent—is continuously withdrawn to a cyclone collector, carrying the dust to be deposited in the cyclone, the cleaned gas passing back to the suction side of the fan. The device is designed to accommodate itself to changes in fan speed with change in boiler rating.

For use on the bottoms of soot hoppers, a new soot valve was shown by The Allen-Sherman-Hoff Co. This has a slide gate below which are two nozzles which undercut the soot and wash it into a sluice. An agitating nozzle was also shown for suction pipes of ash pumps. This device is fastened to the bottom of the suction pipe and carried water nozzles through which jets of water discharge to cause turbulence and prevent the inlet from plugging.

For eliminating dust from flue gas of pulverized-flue-fired boilers, a new Dustrap was shown by Green Fuel Economizer Co. This device, installed in the duct carrying the gas, consists of a series of deeply corrugated barbed plates, suspended in a casing to form alternate narrow vertical nozzles and expansion chambers. In passing through these, the dust in the gas is blasted against the barbed surface, to which it adheres through contact and electrostatic action. A rapping device is provided to shake the dust into a hopper from which it it taken by a screw conveyor.

Atwood & Morrill Co. showed its new adjustable damper regulator. Variations in steam pressure admitted to a diaphragm on this regulator cause it to move and transmit its motion to the control valve of a hydraulic cylinder. The piston in this cylinder is connected by a system of levers to a chain working the weighted boiler dampers. The levers are arranged so that by means of a regulating screw the travel of the lever working the damper can be changed from 0 to 15 in. while the hydraulic piston is traveling 15 in.

Steam actuated furnace draft regulator of new design was displayed in operation by National Regulator Co. In this regulator, a bell floating on oil in a reservoir has furnace draft applied to its underside; the bell is suspended on a lever with counterbalancing weights and the vertical motion of the bell is transmitted to a steam inlet valve by a roller on the top of the lever connected directly with the inlet valve stem. This valve in turn admits steam to the top of a piston and the remainder of the action to operate the damper is the same as in the A-Jacks regulator.

The Schaefer bypass, a fitting made by Frank H. Schaefer Co., to be inserted in piping to save space and eliminate joints, as recently described in these columns, was shown.

Attention was called by Murray Iron Works Co. to improvements in the bearing pedestal construction of its steam turbines and the special nozzle arrangements.

New flush-type mounted mercury column vacuum gage, designed for panel board mounting, was exhibited by Taylor Instrument Companies.

For use in its underground pipe conduits, The RicwiL Co. showed its new filter cloth, used to wrap joints in conduit, designed to admit water but to keep out sand. Cast-iron conduit with Loc-liP construction for heavy duty was shown. Cradle bases to increase strength of sewers and act as drain was featured, together with Dry-paC, a waterproof asbestos conduit filler.

Toledo Automatic pipe cutters of new design, as recently described in these columns, were shown by Toledo Pipe Threading Machine Co. There was also shown a new ratchet pipe reamer with cutter blades cast solidly in the head, to be operated by a hand ratchet.

Use of the La Montube screen as side wall and bridge wall construction for boiler furnaces was shown by the La Mont Corp. by actual sections of the tubes set up with headers and outside insulation.

Stockham Pipe & Fittings Co. featured a 12 by 14 in. cast steel tee with side outlet, designed for 600 lb. pressure, to be used as a cross-over in the new Gorgas Steam Plant No. 2 of Alabama Power Co., referred to recently in these columns.

Connery & Co., Inc. had on display a new duct design developed as a result of researches by General Electric Co. in the subject of flow in pipes, undertaken primarily in connection with the design of cross-over pipes between cylinders of steam turbines. These principles were extended further to include air and gas flow. In the new Connery air or gas duct, a right angle turn duct had square corners with vanes to direct the flow of gas or air around the corner. It was stated that this construction decreases the loss in velocity head at such a corner from 150 per cent to 22 per cent, as compared with the loss in a curved or long sweep elbow without vanes or blades.

Coal analyses help to describe the character of coal as it lies in the ground or as it may be delivered to the user, points out the United States Bureau of Mines, Department of Commerce. There is a distinct difference between "mine samples" and "delivered samples." Analyses of mine samples of coal are plentiful, but available analyses of delivered coal are relatively few. Mine samples are collected according to a standard method. The sampler cuts a channel 2 by 6 in. or 3 by 4 in. from roof to floor in the face of the bed and excludes from the sample any partings more than ⅜ in. thick and any lenses or concretions of sulphur or other impurities more than 2 in. in maximum diameter and one-half inch thick.

Analyses of mine samples form a permanent or scientific record of the coal bed at the point sampled; they are important in determining the character of the coal in any given mine or district. When the samples are taken in a standardized manner, these analyses are valuable to the operator. When compared with analyses of delivered coal, they show him whether or not his mine is being efficiently worked or whether the coal is being properly prepared—which involves the question of whether he has suitable mechanical appliances for separating the impurities.

News Notes

WAGNER ELECTRIC CORP., 6400 Plymouth Ave., St. Louis, Mo., announces that H. N. Felton, branch manager of the Milwaukee office since 1927, has been made branch manager of the New York office. The corporation also announces the removal of its Los Angeles branch office and service station to 1220 S. Hope St., Los Angeles, Cal.

H. W. FULLER, vice president in charge of engineering and construction, Byllesby Engineering & Management Corp., Chicago, Ill., has announced that the new 28,000-kw. generating unit in an extension of Station B of the San Diego Consolidated Gas and Electric Co. has been satisfactorily installed and that the unit has been placed in full service.

ENGINEER CO., 17 Battery Place, New York City, announces that Guy L. Warden, its Pacific Coast representative, has moved to 114 West 17th St., Los Angeles, Cal.

C. E. GEORGE, for many years western manager of the American Schaeffer & Budenberg Corp., has recently joined the sales staff of the Taylor Instrument Cos. of Rochester, New York. He will be at the Chicago office of the company, 58 East Washington St., Chicago, Ill.

JULIAN D'ESTE CO., Boston, Mass., announces that it has acquired the exclusive services of W. A. Viets, of Dayton, Ohio, as advisory engineer to promote the sales of equipment recently placed on the market. Mr. Viets was formerly midwestern engineer for Morehead Manufacturing Co. and more recently the sales engineer for Curtis engineering specialties in general.

H. D. SAVAGE, president of Combustion Corporation of America, announces the election of Carl F. Weigel as vice president and general manager of the subsidiary Hedges-Walsh-Weidner Co., Chattanooga, Tenn. Prior to the combination of the Walsh & Weidner Boiler Co. and the Casey-Hedges Co. Mr. Weigel was chief engineer of the Walsh & Weidner Boiler Co. and, from the date of that combination he has served as chief engineer of the combined organization.

OFFICIALS OF the Delaware Electric Power Co., Wilmington, Delaware, have organized a new company under the name of the Delaware Light and Power Co. to consolidate electric light and power property in that section, including the Wilmington Light & Power Co., Wilmington City Electric Co., New Castle County Electric Co. and the American Power Co. Improvements in power facilities and transmission lines will be carried out.

BUFFALO FORGE CO., Buffalo, New York, announces that the year 1928 is the golden anniversary of the founding of the Buffalo Forge Co. The business began in 1878, when Charles F. Brunke and Charles Hammelman, partners, began the manufacture of the portable forge originated by Mr. Hammelman. At the end of the year, the partners sold to W. F. Wendt a half interest in the business. The first shop was located on the fifth floor of the small building at Washington and Perry Sts., Buffalo. The company at first was forced to have its products made by outside machine shops, but by 1880 the business had grown sufficiently to warrant the purchase of its own manufacturing plant, which was a frame building on Broadway near Mortimer, the present location. In 1884, the company entered the heating and ventilating field and in 1888, Henry W. Wendt, brother of W. F. Wendt, was admitted to the firm. In 1903, the Geo. L. Squier Manufacturing Company and the Buffalo Steam Pump Co. were acquired. The former concern was engaged in the manufacture of machinery for sugar, rice and coffee plantations while the Buffalo Steam Pump Co. was established in the manufacture of steam pumps. With the three companies under one control, the business continued to grow and in 1905, was incorporated at a million and a half dollars. In 1914, the three plants afforded employment to more than 1500 workers, most of whom were skilled machinists and mechanics. The executive, sales, engineering and office force numbered about 300. In the early part of 1916, W. F. Wendt sold his entire interest to his brother and the company was then reorganized with the following officers, all of whom are still active: H. W. Wendt, president; E. F. Wendt, vice president and treasurer; H. W. Wendt, Jr., vice president and secretary; C. A. Booth, vice president and sales manager; H. S. Whiting, assistant secretary.

COMBUSTION ENGINEERING CORP. reports that its affiliated company, the Hedges-Walsh-Weidner Co., Chattanooga, Tenn., has recently shipped to the Gulf States Creosoting Co., a large steel drum to be used for pressure creosoting. The shell is 140 ft. long, 8 ft. in diameter and has a plate thickness of 1 in. It weighs some 175 t. and was loaded on five flat cars for shipment. Another interesting shipment was a car tank for nitric acid, 6 ft. 1½ in. inside diameter by 31 ft. 9 in. long, with a capacity of 7000 gal. It is the first of seven stainless steel tanks to be built for E. I. Dupont De Nemours & Co.

ORELITE CO., INC., 109 Broad St., New York, has recently elected the following new officers: S. Janovici, president and treasurer; J. Gilbert Mason, Jr., vice president and secretary; A. Janovici, assistant secretary; M. J. Kaufman, assistant treasurer.

GRAYS HARBOR Railway & Light Co. at Aberdeen, Wash., is modernizing its steam plant and installing new boilers and turbines. The work is being done by Sanderson & Porter, in charge of Mr. Rosenbaum, engineering superintendent of that company. Hogged fuel will be burned. William S. Hill is general superintendent of the Grays Harbor Railway & Light Co. and H. H. Finch is chief engineer.

RAPID PROGRESS is being made in the construction of the new steam electric generating station in the City of Evansville for the Southern Indiana Gas & Electric Co. This station located on the Ohio River will have an electrical installation consisting of one new 12,500-kw. turbo-generator unit with condenser and auxiliaries and one 7,500-kw. turbine to be taken from the Division Street station of the same company. It will contain two 1160-hp. cross-drum boilers, stoker-fired, with economizers, draft equipment, feed water equipment and other necessary auxiliaries. The boiler room is designed to take care of one additional boiler. Intake and discharge tunnels and screen house are designed for an ultimate development of 100,000 kw. Adequate coal and ash

handling facilities are being provided. This new Ohio River steam plant with its 20,000-kw. generating capacity will be interconnected with the existing Division Street plant by three 12,500-v. tie lines through a modern outdoor substation to be constructed next year. The concrete foundations are completed to the point where no further trouble is anticipated from possible high water in the river. Structural steel is being delivered and erection started. Steam and electric equipment is well in hand. The construction work is being carried out by Stevens & Wood, Inc., of New York and Evansville. The total cost of this plant is estimated at $1,750,000 and it will be in service in August, 1929.

Pennsylvania Railroad Co., Broad Street Station, Philadelphia, Pa., has authorized the complete electrification of its lines from New York, or what is known as Manhattan Transfer, Newark, N. J., to Philadelphia, Wilmington, Del., and vicinity, totaling 325 mi., or 1300 mi. of track. The work will require a period of seven to eight years for the completion and is estimated to cost $100,000,000, to be expended at the rate of approximately $15,000,000 per yr., beginning in 1929. Initial work will cover the electrification of the section between Trenton, N. J., and Philadelphia. About 60 per cent of the fund noted will be used for the purchase of electric power equipment, including catenary and overhead transmission line construction, power substations, switching stations and other miscellaneous construction, while 40 per cent will be expended for rolling stock; it is estimated that from 250 to 300 electric locomotives will be required when the system is complete. Contracts for power service have been made with the Philadelphia Electric Co. and the Public Service Electric & Gas Co., and both of these utilities will expand facilities for this purpose. The engineering department of the railroad is in charge of the project.

Celanese Corp. of America, Inc., Amcelle, near Cumberland, Maryland, has awarded contracts for the construction of a large boiler plant at its local rayon mill, giving the construction award to the Hughes-Foulkrod Co., Pennsylvania; boiler units will be furnished by the Babcock & Wilcox Company and stokers by the American Engineering Co. Arthur J. Fitch is works manager.

At the World Engineering Congress to be held in Tokio in the fall of 1929, a sectional meeting of the World Power Conference is planned to discuss the economics of power generation and distribution. Arrangements for the Congress are being furthered in this country by Elmer A. Sperry, president of the A. S. M. E., and have been favored by president-elect Herbert Hoover, who is honorary chairman of the committee and has consented to retain his interest in the work.

Dr. M. Kamo, chairman of the Japanese organizing committee stated, at a recent dinner of the American committee, that engineering concerns, the government and the public in Japan, are giving generous interest and financial support; that Prince Chichibu, heir to the throne will act as patron; that strong delegations will attend from British and European societies, who will present some 100 papers. Good progress is being made and prospects are bright for an important and interesting Congress.

Books and Catalogs

Third edition of Trade Standards, adopted by the Compressed Air Society, has just been published. It has been considerably enlarged and improved and includes numerous illustrations and tables of interest in the various compressor problems. New material includes the description of A. S. M. E. standard air receivers with list of standard sizes; pneumatic tool standards; a section on portable compressors and the section relating to the installation and care of compressors has been amplified and revised. These pamphlets may be obtained at fifty cents each on application to the secretary of the Compressed Air Society, C. H. Rohrbach, 90 West St., New York, N. Y.

Fifth edition of the Standards of the Hydraulic Society has just been published. The principal changes from the preceding edition include revision of the extracts taken from the A. S. M. E. test code for centrifugal and rotary pumps and changes in material recommended for the construction of special service pumps in line with the latest accepted practice. The pamphlet contains 80 pages, is 8½ by 11 in. in size, with many illustrations, and is priced at fifty cents. Copies may be obtained from the secretary of the hydraulic society, C. H. Rohrbach, 90 West St., New York, N. Y.

In a recent, attractively-illustrated, 24-page bulletin, Esterline & Angus, Indianapolis, Ind., discusses the engineering background of the company. Messrs. Esterline and Angus have formerly solicited other engineering business and the booklet gives illustrations and some information about some of the interesting devices they have developed. These include equipment used in the making of automobile tires, testing equipment, devices for handling materials and so on. Now, however, the time of these engineers is taken entirely up by Esterline-Angus Co. so that they no longer solicit engineering business. The bulletin is issued to give an idea of the scope of the work they have done in the past.

Schutte & Koerting barometric multi-jet condensers are described in bulletin No. 5-AA, recently received. The bulletin describes the condensers in detail, discusses their advantages and presents curves of performance data and illustrations of standard and typical applications. These applications, besides the power plant, include units for use in industrial plants such as sugar mills and other processes where vacuum pans are used. The bulletin is sent out by Schutte and Koerting Co., Philadelphia, Pa.

Massachusetts modified unit heaters of two types are described and illustrated in a recent bulletin. One of these is the type V heater, incorporating heat coils and motor-driven fans built as a flow type unit. The type V. F., which is an amplification of type V also includes air filter cells, while the type H unit heater can be arranged either for ceiling suspension or for use with circulating box. The bulletin is sent out by the Bishop & Babcock Sales Co., 4901-4915 Hamilton Ave., N.E., Cleveland, Ohio.

Locke Regulators of all types are described in catalog No. 50 which has just been received. This is a well-illustrated, 72-page booklet. Details of the various hydraulic regulators, combination regulators, furnace

draft regulators, pressure regulators, balance valves and reducing valves are given, and a special section is devoted to engine and turbine stops, throttle valves and speed limiting devices. Tables of dimensions are given, together with engineering data on steam flows, and the bulletin is attractively illustrated and the data presented in the most modern manner. It is published by the Locke Regulator Co., Salem, Mass.

DATA SHEETS sent out by the Hoist & Crane Engineering Co., 114 Liberty St., New York City, show details of insulators, brackets, conductor supports and other equipment used in electrifying overhead track for electric hoists and cranes.

IN A RECENT 200-page book, copiously illustrated, and containing many diagrams, drawings, dimension tables and other engineering data, the Ashton Valve Co., Boston, Mass., describes the Ashton pop safety and release valves, pressure and vacuum gages, locomotive and power plant specialties. Complete engineering data are given on the various devices, together with price lists.

CONCO CRANES and trolleys are completely described in a recent 48-page bulletin by H. D. Conkey & Co., Mendota, Ill. Various types of cranes for handling material in general manufacturing plants are illustrated with tables of dimension drawings, while the last part of the bulletin describe Conco cranes and clam shell buckets for handling bulk material.

"ELECTRIC HEAT in General Electric Factories" is the title of a recent, well-illustrated bulletin, No. GEA-1012, describing how the General Electric Co., Schenectady, N. Y., employes electric heating in its manufacturing processes. These include annealing and heat-treating steel, annealing copper and brass, enameling, melting metals and several other types of ovens and furnaces.

AUTOMATIC PUMPING, with vacuum pump primer, is discussed in a recent 8-page, illustrated bulletin. This bulletin, No. 850, describes the method used to make suction-lift centrifugal pumps automatic and is published by Barrett, Haentjens & Co., Hazleton, Pa.

ROLLER-SMITH Co., 233 Broadway, New York, announces a new instrument type HEA-3 polyphase ammeter, which is illustrated and described in supplement No. 1 to bulletin 450. The specific application of this instrument is for 3-phase alternating current circuits. The type HEA-3 ammeter is designed to make possible simultaneous readings in each of the phases of a 3-phase circuit. This arrangement is intended to show the observer at a glance whether or not the phases are properly balanced. The meters have a 7⅛-in. scale and are designed to occupy relatively small space.

ARC WELDING APPLICATION in manufacturing is discussed in a pamphlet issued by the Lincoln Electric Co. of Cleveland, Ohio. Redesign of machinery to permit construction by welding methods is described and illustrated, showing the use of standard steel shapes in place of castings.

CAST-IRON Column Sizes and Safe Loads is the title of a booklet issued by Paul Wright & Co., Birmingham, Ala., which gives details of construction and plans for use of these columns in building construction. They are cast vertically in dry sand molds or centrifugally in metal molds, the former method being used for columns with greater thickness and load-carrying values, and the ends are machined square to the axis of the column. Uses for mill construction, for steel-framed structures and for reinforced concrete are shown.

TWELVE PRACTICAL Foundry Mixtures showing plain steel or iron and corresponding nickel-steel or nickel-iron for like purposes are given in a booklet issued by The International Nickel Co., 67 Wall St., New York. The mixtures are for various services and forms of castings and advantages of the mixtures using nickel are explained.

FLEXIBLE SHAFT MACHINES, including grinders, buffers and other small tools, are described, with complete details of the flexible shaft, in a recent booklet sent out by Stow Manufacturing Co., Inc., Binghamton, N. Y.

IN A FOLDER received from the Brown Instrument Co., Philadelphia, Pa., is shown the complete meter equipment for measuring temperatures, fluid flow, liquid levels, pressure vacuum and carbon dioxide installed in the plant of the Indian Refining Co. of Lawrenceville, Ill., for the operation of its stills, by the use of diphenyl, which is used to obtain higher temperatures than would be possible with steam.

OBROUND CONDULET for electric wiring, incorporating a wedge nut construction, is described and illustrated in an 8-page bulletin sent out by the Crouse-Hinds Co., Syracuse, N. Y.

IN A RECENT FOLDER, the Vib-Restor for centrifugal pumps is described. This is a device intended for installation in the suction and discharge lines of centrifugal pumps close to the pump to eliminate noise and vibration in the piping system. The Vib-Restor consists of a length of special rubber hose with suitable couplings at the ends designed to take the place of metal piping, between intake and pump and between pump and outlet. It is a recent product of Chicago Pump Co., 2336 Wolfram St., Chicago.

HANDBOOK OF SMALL BELT DRIVES is a well-illustrated, 44-page book recently issued by L. H. Gilmer Co., Tacony, Philadelphia, Pa. It describes Gilmer belts, discusses the design of pulleys and various types of drives, fundamental principles of belt drives and other engineering subjects. The illustrations show clearly a great many interesting applications of all types of belts.

"COMPETITORS WHO HAVE Coöperated to Improve Quality" is the title of an illustrated booklet being sent out by Electric Steel Founders Research Group, 541 Diversey Parkway, Chicago, Ill., giving information regarding a unique organization of manufacturers of steel products who have conducted a pioneering effort in industrial research.

TYPE AA RELIANCE fully-enclosed fan-cooled induction motors with ball bearings are described in bulletin No. 103 by Reliance Electric & Engineering Co., Ivanhoe Road, Cleveland, O.

LOW-LEVEL MULTI-JET CONDENSERS are described in detail in bulletin 5-A, just issued by Schutte & Koerting Co., Philadelphia, Pa. This bulletin supersedes the data on this type of condenser given in Volume 2 of

the company's Condenser Catalog previously issued. It is attractively illustrated with colored wash drawings to show the details of condenser and the general method of using it with various types of prime movers. Interesting photographs of its many applications are included. Advantages of the multi-jet condensers are discussed and performance curves are given together with tables of sizes and capacities for the use of designers. Besides its use with steam turbines and engines, other applications of the condenser are shown such as in refrigeration, drying, oil refining and other industrial processes. The bulletin contains data on condenser piping, air leakage and other data of general interest to engineers.

COLLINS WATER-TUBE BOILERS are described in detail with cross sections and photographs of typical installations in Catalog B, recently issued by Southwestern Engineering Corp., 1221 Hollingsworth Building, Los Angeles, Cal.

CRYSTALITE water softeners are discussed in a recent bulletin 183 by the International Filter Co., 333 West 25th Place, Chicago. This 16-page, well-illustrated booklet, discusses the chemistry of zeolite water softener, the early history and development of zeolites, crystalite, the advantages of upflow softening and is illustrated with curves and details of the adaptation of crystalite to upflow softening, with many installations of softeners of this type.

IN A COMPREHENSIVE, well-illustrated 160-page catalog, complete data are given regarding speed reducers. The first pages of the book deal with various types of planetary spur gear reducers and generated continuous tooth herringbone speed reducers, and are followed by tables of detailed dimensions and sketches. Then follow illustrations showing applications of these reducers to all types of industrial drives. Right-angle planetary spur gear reducers are then illustrated and described in detail with tables of dimensions, followed by similar data on worm gear speed reducers. The book, catalog No. 166, is issued by D. O. James Manufacturing Co., 1120 W. Monroe St., Chicago, Ill.

SERIES 78 thermostatic traps for process steam pressure from 10 to 100 lb. per sq. in. are illustrated and described in a recent 12-page bulletin No. 30C23 just issued by Warren Webster Co., Camden, New Jersey. Another bulletin, No. 30C, describes in detail Webster vacuum systems of steam heating.

SIROCCO UNIT HEATER, designed primarily for industrial heating, is described and illustrated in a recent attractive bulletin. The heater consists of a fan assembly, a copper tube heating element, and suitable housing and discharge tubes. It can be mounted in various ways and the booklet shows many interesting photographs of its applications, together with dimension drawings and tables of capacity. This bulletin is sent out by the American Blower Corp., Detroit, Michigan.

"THE BELT that puts the Pull in the Pulley" is the title of a recent bulletin issued by E. F. Houghton & Co., 3d, American & Somerset Sts., Philadelphia, Pa. This discusses the characteristics of good belts, costs of belt operation, wear, and other features, together with care of leather belting and gives a large amount of engineering data on methods of using and handling belts. Characteristics of the company's Vim leather belting are discussed. In another 24-page bulletin, Houghton's Absorbed Oils are described and recommendations are given for their application to all types of industrial equipment. A third illustrated booklet tells the story of Vim leather, describing in detail all the processes used in the preparation of this leather.

THERMIX STACKS are discussed in a 24-page well-illustrated bulletin just received. This gives details of the stacks and fans incorporated in them, cross sections and photographs of actual installations and engineering data regarding their selection and operation. The bulletin, No. 14, is published by Prat-Daniel Corp., 183 Madison Ave., New York City.

LONGITUDINAL DRUM water-tube boilers are described in detail with many ilustrations in a recent 54-page bulletin sent out by the Union Iron Works, Erie, Pa. This contains detailed discussion of the construction and operation of this boiler, illustrates typical installations of it and also shows detailed cross sections.

"FAULKNER'S IMPROVED BOND in the Modern Boiler Plant" is the title of a booklet recently issued by The J. A. Faulkner Refractories Co., 523 W. Federal St., Youngstown, O. The bulletin discusses the characteristics and operating performance of Faulkner's bond, narrates typical experiences with it under hard service, discusses methods of using it and illustrates typical settings laid up with the bond.

WESTINGHOUSE ELECTRIC AND MANUFACTURING CO. has recently issued leaflet 20,369, a publication on enclosed synchronous condensers. There are two types of these machines—semi and totally enclosed. Both types have electrically welded plate steel frames. In the semi-enclosed type, the cooling air is drawn in along the shaft and forced through the machine by fans on the rotor. The warm air is discharged around the periphery. In the totally enclosed type, the air is drawn through the outer end bells at the bottom of the machine and is discharged at the top.

"WASP AND HORNET ENGINES and their use of Nickel Steel" is the title of a recent bulletin issued by the International Nickel Co., 67 Wall St., New York City. This bulletin discusses the use of nickel steel in the construction of Wasp and Hornet fixed radial type air-cooled engines and gives general specifications for both engines.

WORTHINGTON EQUIPMENT for buildings is treated comprehensively in a 28-page bulletin No. WP-1003, just issued by the Worthington Pump & Machinery Corp., 2 Park Ave., New York City. The bulletin illustrates and discusses the use of steam and electric pumps for heating systems, vacuum pumps, well pumps, fire protection equipment, pumps for elevators and lifts, meters for cold water, oil and condensate and air compressors.

STANDARD STEEL BUILDINGS of copper-bearing, galvanized steel, designed for the use of all industries, are discussed in a recent well-illustrated 38-page bulletin sent out by Blaw-Knox Co., Pittsburgh, Pa.

IDEAL SYSTEM of lubrication is described and illustrated in a 12-page bulletin published by the Ideal Lubricator Co., 2120 Packard Bldg., Philadelphia, Pa.